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# The use of open and closed backwater ponds of the Missouri River, Iowa as spawning and nursery areas for fish

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The use of open and closed backwater ponds of the Missouri River, Iowa as spawning and nursery areas for fish

by

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## ABSTRACT

Adult and young-of-the-year fish were collected in backwater ponds of the channelized Missouri River, Iowa to determine the use of the ponds as spawning and nursery areas by fish. Based on catches of running-ripe adults and large catch per effort of small larvae, at least 15 species spawned in the study ponds. Catches of larvae in tow nets were generally more than 10 times greater in the ponds than reported in the main channel drift from other studies.

More species of adults and young-of-the-year fish were captured in ponds which were connected with the main channel of the river by notches (environmental gaps) than in ponds which were separated from the river.

Severe winterkill occurred in all study ponds as a result of low water levels during the nonnavigation season. Adult fish repopulated open ponds during the spring spawning season, but only those species which were able to survive the harsh winter conditions were present to spawn in closed ponds.

Zooplankton densities in the study ponds were more than 25 times greater than reported in the main channel drift from other studies. Although Van Dorn bottle samples were similar among open and closed ponds, Miller and tow net samples indicated a greater abundance of zooplankton in closed ponds than in open ponds.

Stomachs of young-of-the-year carp (*Cyprinus carpio*), sunfish (*Lepomis* spp.), and crappie (*Pomoxis* spp.) from closed ponds contained greater numbers of zooplankton than did stomachs of fish captured from open ponds.

Degradation (lowering of elevation) of the channel bed and water table of the river has resulted in a lowered water level in the back-waters. Sediment deposition in backwater areas has also eliminated valuable fish habitat. The continued existence of backwater areas will be limited unless main channel degradation can be controlled.

# INTRODUCTION

The Missouri River as it exists today is an extremely controlled and regulated river. Five upstream reservoirs and an extensive network of channelization structures have been used to meet the historic objectives of river management: flood control, bank stabilization, land reclamation, power generation, and formation and maintenance of a navigation channel (Sayre and Kennedy 1978). Whereas the management of the river has effectively met the historic goals, by creating a narrow, uniform channel with a swift current, the diversity and amount of habitat available to fish has been greatly reduced. Increased sediment-transport capacity of the river caused by reservoirs and channel straightening has resulted in downstream degradation of approximately 2 m in the last 10 years. Backwaters of the river have either been filled in with sediment or have been separated from the river by channelization structures and main channel degradation. During the period 1879-1972, 60,875 river acres, 50% of the original surface area, were lost in Missouri as a result of the river management program (Funk and Robinson 1974).

The U.S. Army Corps of Engineers is currently conducting a "Riverine Habitat and Floodway Restoration Project" in an effort to remedy some of the damage that has been done by their river management programs. Dikes and revetments have been notched to allow water to flow behind them, both opening habitat up to the river, and in some cases creating new habitat by washing out sediment that has been deposited below the dikes. Notches, or "environmental gaps," have been constructed in about 300 dikes and revetments between Sioux City, Iowa and the mouth of the Missouri River.

The value of these notches for fish has not been evaluated.

The present study examined three small, shallow ponds which were connected with the main channel of the river by notches (open ponds) and two ponds which were separated from the main channel by dike and revetment structures (closed ponds). The main channel of the river is defined by channelization structures which create a mean channel width of approximately 240 m and depths greater than 3 m (Morris et al. 1968). The study was conducted from May through August, 1978 between River Mile 700 and 709 in Woodbury and Monona Counties, Iowa, about 25 miles south of Sioux City, Iowa (Figure 1).

The primary objective of this study was to determine the effect of opening backwater ponds to the river on the use of these ponds by fish as spawning and nursery areas. Adult, juvenile, and larval fish were collected to determine the relative numbers and kinds of fish that were using the study ponds. In addition, zooplankton samples were collected to determine the kinds and abundances of fish food organisms; larval fish gut contents were examined to determine fish food habits; and growth of young-of-the-year fish was determined to assess the suitability of the ponds as spawning and nursery areas for fish.

Few studies of backwater ponds of the channelized Missouri River have been published. Kallemeyn and Novotny (1977) studied fish populations in the unchannelized and in the channelized river bordering Iowa, including two of the open ponds examined in the present study. They found that many species of fish preferred backwater areas of the river and that backwaters and marshes of the unchannelized river were extremely important to the river system as spawning and nursery grounds for fish. Because

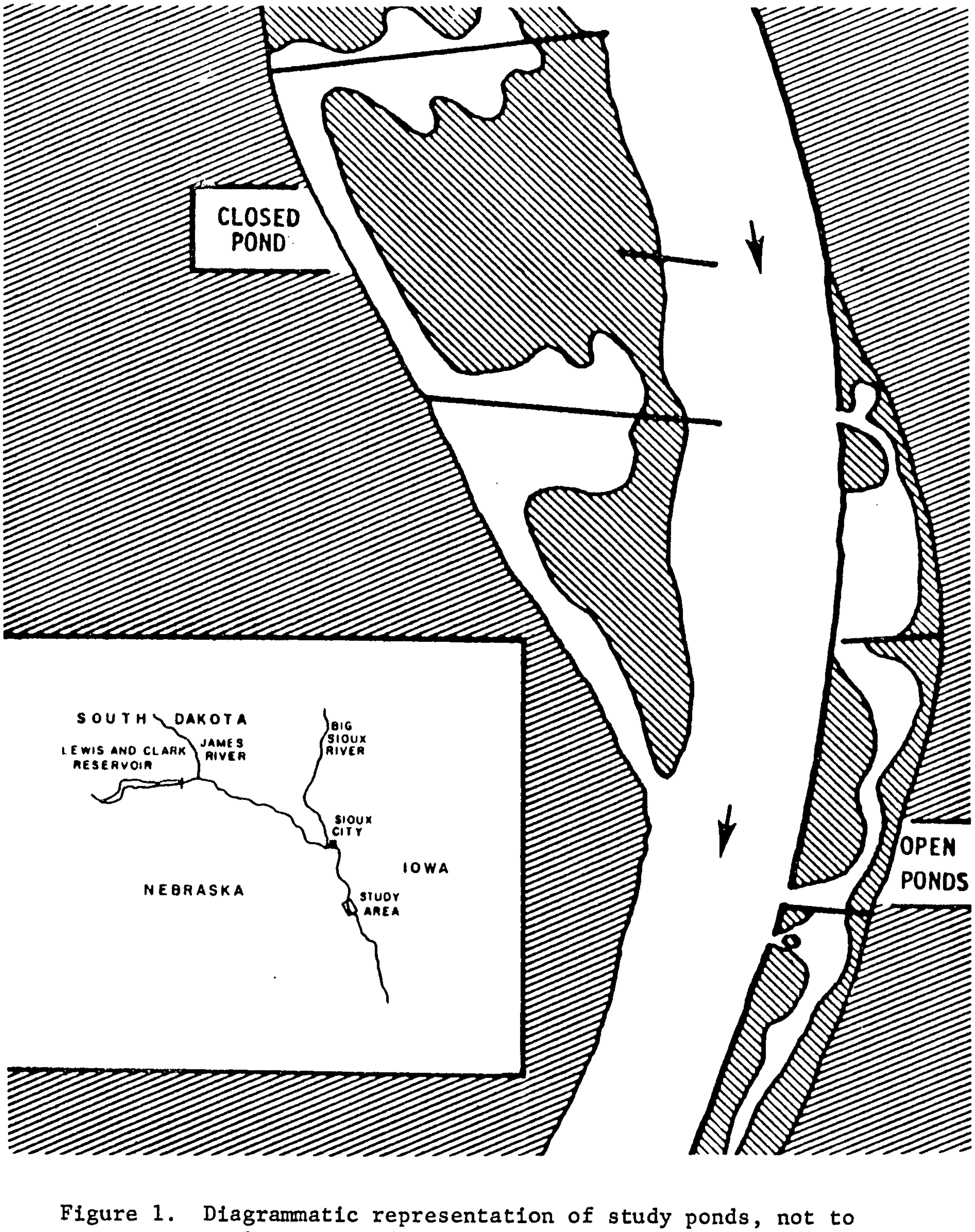



Figure 1. Diagrammatic representation of study ponds, not to scale. River dimensions are reduced to illustrate location of ponds in relation to main channel

of large catches of juveniles in backwater ponds of the channelized river, Kallemeyn and Novotny (1977) hypothesized that fish used the ponds as spawning and nursery areas.

Welker (1963) studied adult fish populations in five open and closed oxbow lakes of the river in Iowa. He did not note any major differences in species composition among open and closed ponds, but he did note that only two goldeye (Hiodon alosoides), both over 300 mm (12 inches), were captured in closed oxbows. He hypothesized that the goldeye were unable to reproduce successfully in the closed lake environment.

Hey and Baldwin (1977) sampled fish from backwater ponds of the channelized river near Sioux City, Iowa, and found evidence of severe winterkill in the shallow ponds. They did not study the use of backwater ponds as spawning and nursery areas, but felt that these locations were probably heavily utilized by many species of fish (Jane Hey, Briar Cliff College, Sioux City, Iowa, personal communication, 1978).

# MATERIALS AND METHODS

## Physical Description of Study Areas

Surface area of each study pond was determined from aerial photographs and on-site measurements, or by plane table and alidade. Water depths were determined by sounding line and rod. Water surface elevations were recorded daily from permanent staff gauges. Surface water temperatures ($^{o}$C) and Secchi disc readings (cm) were determined on each collection date.

## Fish Sampling

Adult fish were captured from May to October, 1978, using trap net, seine, and shocker. The trap net was constructed of 1.3 cm mesh netting and had a 16.4 m lead and a 0.9 x 1.7 m opening. The bag seine was 7.6 m in length with a 0.6 cm mesh bag and 1.3 cm mesh wings. A 230 V. D.C. shocker and a 110 V. D.C. shocker were also used for routine collections. The spawning condition of adult fish was determined by gently squeezing the fish's abdomen for sex products during spawning periods. Throughout this paper, the common names of fish will be used; scientific names and common names are listed in Appendix A.

Young-of-the-year (y.o.y.) fish were collected weekly during May and twice weekly in June when weather permitted using tow net, Miller sampler, seine, and trap net. Tow net and Miller sampler catches were expressed as the number of fish captured per 100 $m^3$ of water filtered; seine catches were expressed as the number of fish captured per 100 $m^2$ surface area seined; and trap net catches were expressed as the number of fish captured per overnight (12-hr) set. Young-of-the-year collections began after sunset and continued until approximately 3 AM to diminish the clustering effects of fish schooling (Mayhew 1977). A modified 0.5 m tow net was towed by hand a measured distance (280-320 m) across shallow bays by two persons. The tow net was 0.8 mm square mesh nylon with an attached cup containing 0.9 mm screen. A 10.2 cm perforated plastic pipe roller was attached to the bottom of the support frame so that the net could be pulled without becoming clogged with bottom sediments. An average of 60 $m^3$ of water was filtered per sample. Towing speed was approximately 1.5 m per second. Collections were also made with a pair of Miller samplers (mesh size = 0.8 mm) near the surface for 4 min at speeds of about 8 km per hr. Approximately 16 $m^3$ of water were strained during three tows at each site on each sampling date.

Larval fish were preserved upon capture in 3% formalin and later stained with rose bengal dye (Mitterer and Pearson 1977) to aid in detecting and sorting the fish from debris. Samples were examined twice to assure detection of all individuals.

Most larval fish were identified to genus using Fish (1932), Hogue et al. (1976), May and Gasaway (1967), and Lippson and Moran (1974). Catostomids and cyprinids except for carp and fathead minnow were identified to family because of difficulties in separating them into different genera while still in larval stages. Lepomis spp. will be referred to as sunfish in this paper.

Seine hauls captured y.o.y. and adult fish. The trap net set overnight at each site for adults also captured juvenile fish later in the season. Fish older than Age-0 were identified, measured for total length (mm), and released. Young-of-the-year were preserved in 10% formalin for later identification and measurement.

Total length (TL) of each larva was measured to the nearest millimeter. Mean total lengths were determined by combining data from catches of all gear types for a given date at each pond. Linear regression formulae describing the growth of eight species of fish were then calculated.

## Food Habits

Larvae used for determining food habits were washed in distilled water to remove externally attached organisms, and placed under a binocular dissecting microscope. The digestive tract was removed by forceps and placed on a slide. All food organisms were identified and counted under a compound microscope. Food items in the oral cavity were not examined because of the possibility that they were ingested after collection. Computations of the mean number of organisms per stomach were based on stomachs with and without food.

## Zooplankton

Zooplankton samples were collected with a 2-liter Van Dorn bottle approximately 10-20 cm below the water surface in the limnetic zone at the same locations and dates as for larval fish samples. Eighteen liters of water from each sampling effort were strained through a 0.11 mm mesh Wisconsin plankton net. Plankton were preserved in 3% formalin, and rose bengal dye was added to aid in the identification and enumeration of organisms. For enumeration, each sample was adjusted to 100 ml in a museum jar. The jar was then inverted several times to randomly distribute the plankton after which a 2 ml subsample was rapidly extracted from the center of the jar and placed in a Sedgwick-Rafter counting cell. Organisms in three 2 ml subsamples totaling 6% of the sample, were counted and identified under a compound microscope using Pennak (1953) and Edmondson (1959). The coefficient of variation for counts ranged from 12 to 142. Plankton densities were expressed as numbers per 100 liters of water sampled.

# RESULTS

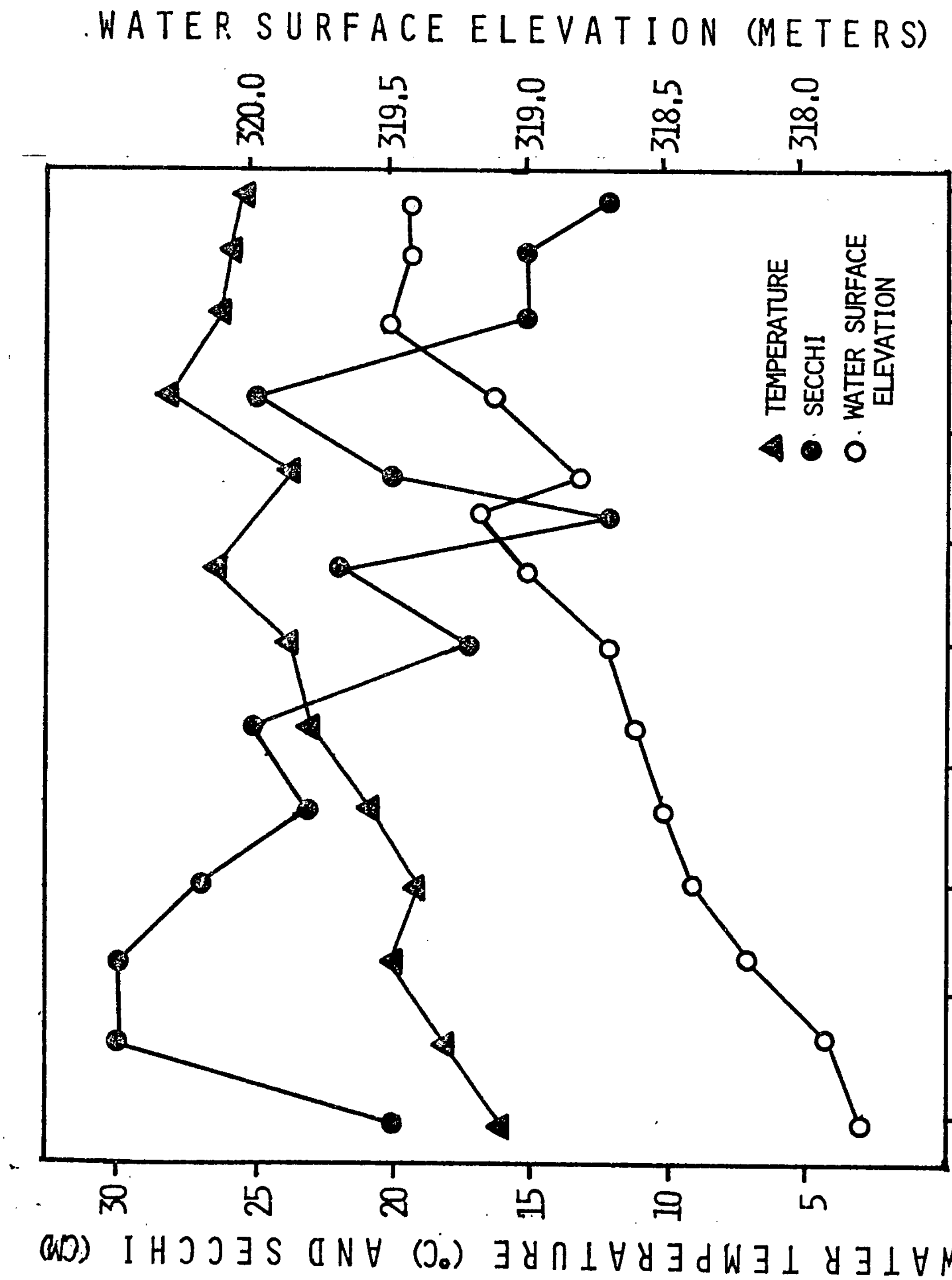
## Water Levels

Water levels in the study area were controlled by releases from Gavins Point Reservoir, located approximately 150 km upstream. Inflows from the James River, the Big Sioux River, and from several small tributaries did not significantly affect water levels in the study area. There was little daily variation in releases from Gavins Point Dam during a 24-hr period; however, there were great seasonal variations. Releases during the navigation season (mid-March to mid-November) average over 900 $m^3$/sec while during the nonnavigation season they are usually less than 575 $m^3$/sec. During the study period May 12-August 4, 1978, daily flows greatly exceeded the normal navigation season discharges, and averaged about 1300 $m^3$/sec. Water surface elevations rose fairly steadily during the sampling period (Figure 1) because of increased releases from Gavins Point Reservoir. The water level was high enough to connect closed ponds with the river after July 1.

## Turbidity

It is widely recognized that suspended solids in aquatic systems affect water quality. Suspended solids have significant effects on community dynamics when they interfere with light transmission (Sorenson et al. 1977). Mainstem reservoirs have greatly increased the water clarity of the Missouri River (Morris et al. 1968). Main channel Secchi disc readings ranged from 12-30 cm and averaged approximately 23 cm during the study period (Figure 2). Upstream rains and runoff caused increased turbidities. High turbidity was also associated with spring snowmelt;

Figure 2. Water level (m), temperature ($^{\circ}C$), and Secchi disc (cm) in the main channel, May through August, 1978


WATER SURFACE ELEVATION (METERS)
320.0
319.5
319.0
318.5
318.0
WATER TEMPERATURE (°C) AND SECCHI (CM)
30
25
20
15
10
5
15
25
5
15
25
5
15
25
5
MAY
JUNE
JULY
AUG
TEMPERATURE
SECCHI
WATER SURFACE ELEVATION

Secchi disc readings of 2 cm were noted during March in both the main channel and in open ponds.

Secchi disc readings in the open ponds were normally 10-15 cm greater than in the main channel. Reduced current velocities in the ponds caused sediment deposition, especially just inside the gaps which connected the ponds with the main channel. Deposition was evident in all open ponds. Pond 2 was accessible during June of 1977, but the formation of a small island just inside the pond prevented boat entry during early May, 1978.

River transported sediment did not enter closed ponds until they were connected with the main channel. Ponds between the closed ponds and the main channel acted as silting basins and reduced the amount of sediment entering closed ponds. Hence, Secchi disc readings were much greater in closed ponds than in open ponds. During May and early June, the bottoms of both closed ponds were clearly visible (Secchi disc readings greater than 1.5 m). Planktonic and organic turbidity reduced Secchi disc readings to 40-50 cm in closed ponds after early June.

## Water Temperatures

Surface water temperatures can affect the distribution, spawning time, and growth of fish. Main channel surface water temperatures ranged from 16 $^{o}$C during mid-May to 28 $^{o}$C during mid-July (Figure 2). Temperatures in the shallower areas of ponds were affected by air temperatures and showed minor variations from temperatures observed in the main channel. Temperature stratification was occasionally noted in bays of Pond 5 that were protected from the wind. Open ponds were well-mixed by wind action, and temperature stratification was not observed.

## Winter Conditions

Management of the river for navigation and flood control requires that main stem reservoirs hold back water during the winter nonnavigation season. The reduction in discharge causes the water level in the main channel to be 1.5-2 m lower than during the summer navigation season. Backwaters in subsurface connection with the river are partially or wholly drained during the winter season; water depth and surface area of the ponds are greatly reduced. These conditions promote winterkill of fish in the ponds. Winterkill is a common occurrence in shallow midwestern ponds (less than 5 m deep) during winters of prolonged snow and ice cover (Greenbank 1945, Schneberger 1970). The winter of 1977-78 was unusually cold and long, and during late winter the main channel of the river was frozen over for several days. Ice on the ponds was cloudy, but snow had blown off a few days before the ponds were visited. Dissolved oxygen readings were taken in the ponds during February, 1978. Readings were less than 10 ppm in all ponds and as low as 2.6 ppm in Pond 5. Open ponds probably received some oxygenated water from the main channel through the stone revetments.

Hundreds of dead fish littered the shores of all ponds in late May, 1978. Hey and Baldwin (1977) reported low water levels and complete winterkills in 8 out of 9 shallow Missouri River backwater ponds during 1976. All study ponds showed evidence of severe winterkill during the winter of 1977-78 and winterkills can be expected to occur on a regular basis.

## Pond Descriptions

Each study pond was unique. Physical characteristics of the study ponds were determined by the basin morphometry and by the relation of the ponds to the river. Some ponds, such as Ponds 2 and 5, had relatively extensive areas of emergent vegetation whereas, others such as Ponds 1 and 3 had steep shorelines and relatively small areas of emergent vegetation. In general, each pond represented a slightly different stage in the successional continuum from riverine to terrestrial habitat. Pond 3 was nearly riverine in character because of the current flowing through the pond. Pond 5, at the other end of the continuum, had no current flow and contained substantial amounts of emergent and submerged vascular aquatic vegetation.

Pond 1, the smallest of the study ponds, had a surface area of 0.40 to 0.52 ha during the 1978 study period (Table 1). Maximum depth ranged from 2.0 to 3.3 m. This pond, located between a stone and wood-piling revetment and the old bank of the river, was connected with the main channel near its downstream end through a 3-m gap cut in the revetment in the spring of 1977. Current did not flow through the gap although sediment from the river was deposited in the pond, especially at the downstream end. The shore adjacent to the river was firm silt and sand and gradually sloped; the opposite shore was a steep bank. A shoreline of firm silt and mud was present in May, 1978 when the water level was relatively low but high water after May flooded shoreline vegetation. A small stand of cattails was present at the downstream end of the pond but no submerged vascular aquatic vegetation was present at any time during the season.

Table 1. Physical characteristics of the study ponds, 1978. Area is in hectares, depth in meters

| Month | Parameter | Open ponds 1 | Open ponds 2 | Open ponds 3 | Closed ponds 4 | Closed ponds 5 |
|---|---|---|---|---|---|---|
| May | Area | 0.40 | 1.66 | 0.81 | 0.86 | 6.90 |
| | Mean depth | 1.3 | 0.7 | 1.6 | 1.7 | 1.3 |
| | Maximum depth | 2.0 | 1.3 | 3.4 | 2.5 | 2.7 |
| June | Area | 0.46 | 1.82 | 0.91 | 0.88 | 7.57 |
| | Mean depth | 2.0 | 1.4 | 2.2 | 2.4 | 2.0 |
| | Maximum depth | 2.7 | 2.0 | 4.1 | 3.2 | 3.4 |
| | Percentage of shoreline composed of rock rip-rap | 16 | 3 | 42 | 21 | 19 |
| | Shoreline development index[a] | 1.2 | 2.6 | 1.9 | 1.3 | 3.5 |
| July | Area | 0.52 | 1.96 | 1.10 | 0.93 | 8.14 |
| | Mean depth | 2.6 | 2.0 | 2.8 | 3.0 | 2.5 |
| | Maximum depth | 3.3 | 2.6 | 4.7 | 3.8 | 4.0 |
| August | Area | 0.52 | 1.96 | 1.10 | 0.93 | 8.30 |
| | Mean depth | 2.6 | 2.0 | 2.8 | 3.0 | 2.5 |
| | Maximum depth | 3.3 | 2.6 | 4.7 | 3.8 | 4.0 |

[a] $D_L$ = (L/2) X A where L = length of shoreline in meters, A = surface area in square meters.

Pond 2, located behind a revetment structure, was long and narrow with a surface area of 1.66-1.96 ha and a maximum depth of 1.3-2.6 m during the 1978 season. This pond was connected with the river near its upstream end by a gap approximately 2.5 m wide cut during the fall of 1975. Current did not flow through the pond but eddied into the gap and deposited sediment to form a small island. Shoreline was similar to Pond 1 but there were more extensive areas of cattails and other emergent vegetation in Pond 2 after May. No submerged vascular aquatic vegetation was present.

Pond 3 was unique because current flowed through the pond from a gap at the upstream end out a gap at the downstream end. This rectangular pond was located behind a stone revetment structure. Surface area ranged from 0.81-1.10 ha, and maximum depths were 3.4-4.7 m. A sand-silt bar was present just below the upstream gap. A greater percentage of the shoreline was rock rip-rap than in any of the other ponds, and the shoreline opposite the river was a steep bank. A small amount of cattails and other emergent vegetation was present after June, but there was no submerged vascular aquatic vegetation.

Pond 4, located immediately upstream from Pond 1, was roughly rectangular in shape with a surface area of 0.86-0.93 ha and maximum depths of 2.5-3.8 m during the 1978 sampling season. In May shorelines were bare mud; after May emergent and terrestrial vegetation were innundated. Small patches of submerged vascular aquatic vegetation were present after late June. Pond 4 was connected with Pond 1 when high water covered the dike separating the two. The ponds were connected overnight on June 20 when high water entered the pond from the downstream end. They were reconnected on July 1 and remained connected through the remainder of the sampling season.

Pond 5, located on the floodplain between two long wing dikes was considerably larger (6.9-8.3 ha) than the other ponds but not significantly deeper 2.7-4.0 m). Approximately 20% of the shoreline was stone and wood-piling dikes. Most of the remaining shoreline was cattails and emergent vegetation in May when water levels were low, unlike the other ponds studied. Submerged vascular aquatic vegetation was abundant after mid June. The pond was connected with another backwater pond which in turn was connected with the main channel after July 1, when high water topped the downstream wing dike shore of Pond 5.

Rock rip-rap and emergent vegetation provided suitable spawning substrates for many species of fish. Most species can be classified by their use of a particular substrate for spawning (Balon 1975), but many species are able to utilize a variety of substrates if the preferred type is not available. According to Balon, emergent vegetation provides good spawning substrate for shortnose gar, white bass, carp, bigmouth buffalo, white crappie, black crappie, and yellow perch. Emergent vegetation was present in Pond 5 during May and in all other ponds after May. Rock, rubble, or gravel are suitable spawning substrate for the bigmouth shiner, shorthead redhorse, white sucker, black bullhead, white bass, green sunfish, bluegill, yellow perch, sauger, and walleye (Balon 1975). Rock rip-rap was present in all study ponds. The river carpsucker and sand shiner are species which spawn over a sandy bottom (Balon 1975). Sand substrate was available in all open ponds, particularly in Pond 3 where current prevented the deposition of silt on the sand immediately inside the gap. The fathead minnow, tadpole madtom, channel catfish, johnny darter, and flathead catfish may be classed as speleophils (Balon 1975). Members of this group guard their spawn in holes or in specially constructed cavities. The cracks among the rock rip-rap would be suitable spawning substrate for at least some speleophils. Steep banks below the water surface may have provided suitable sites for the construction of cavities. However, banks were not below the water surface until July in most ponds and were probably not utilized at that late date. Balon (1975) classified the goldeye, gizzard shad, emerald shiner, and freshwater drum as pelagophils or open water spawners. There were suitable spawning substrates in all ponds for most of the open water species encountered. However, flowing water, which is often preferred by some species, was present only in Pond 3.

## Catches of Adult Fish

Adult fish were collected to determine which species were present in the study ponds during the spring spawning period. Adults of 27 species of fish were captured by trap net and shocker in the five ponds during May and June. Twenty-six species were taken in open ponds, whereas only twelve were captured in closed ponds (Table 2). The creek chub (one specimen) was the only species captured in closed ponds but not in open ponds. Other workers have also reported that more species utilized open backwaters than closed backwaters (Garmon 1890, King 1976, Lambou 1960).

In Pond 1, twenty-one species were captured by trap net and shocker during the May and June spawning season (Tables 2, 3). Male carp, river carpsucker, yellow perch, and female goldeye captured in May were running

Table 2. Number and percentage composition of adult fish caught with trap net in the study ponds during May and June, 1978

| Taxonomic group | Open ponds | | | | | | Closed ponds | | | | Open ponds | | Closed ponds | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | | | | | | |
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Shortnose gar | 11 | 5.9 | 8 | 9.3 | 20 | 37.0 | | | | | 39 | 11.9 | | | 39 | 5.1 |
| Gizzard shad | | | 1 | 1.2 | | | | | | | 1 | 0.3 | | | 1 | 0.1 |
| Goldeye | 10 | 5.3 | 4 | 4.7 | 4 | 7.4 | | | | | 18 | 5.5 | | | 18 | 2.3 |
| Carp | 10 | 5.3 | 3 | 3.5 | 3 | 5.6 | 3 | 2.9 | 8 | 2.4 | 16 | 4.9 | 11 | 2.5 | 27 | 3.5 |
| Creek chub | | | | | | | | | 1 | 0.3 | | | 1 | 0.2 | 1 | 0.1 |
| River carpsucker | 30 | 16.0 | 27 | 31.4 | 9 | 16.7 | | | | | 66 | 20.1 | | | 66 | 8.6 |
| White sucker | 1 | 0.5 | | | | | 5 | 4.8 | 1 | 0.3 | 1 | 0.3 | 6 | 1.4 | 7 | 0.9 |
| Smallmouth buffalo | 3 | 1.6 | 1 | 1.2 | | | 1 | 1.0 | | | 4 | 1.2 | 1 | 0.2 | 5 | 0.6 |
| Bigmouth buffalo | 2 | 1.1 | 3 | 3.5 | | | | | 2 | 0.6 | 5 | 1.5 | 2 | 0.5 | 7 | 0.9 |
| Shorthead redhorse | 2 | 1.1 | 5 | 5.8 | | | 2 | 1.9 | | | 7 | 2.1 | 2 | 0.5 | 9 | 1.2 |
| Black bullhead | 11 | 5.9 | | | | | 38 | 36.5 | 70 | 20.6 | 11 | 3.4 | 108 | 24.4 | 119 | 15.4 |
| Channel catfish | 3 | 1.6 | 3 | 3.5 | 2 | 3.7 | | | | | 8 | 2.4 | | | 8 | 1.0 |
| Stonecat | 1 | 0.5 | | | | | | | | | 1 | 0.3 | | | 1 | 0.1 |
| Tadpole madtom | 1 | 0.5 | | | | | 26 | 25.0 | 37 | 10.9 | 1 | 0.3 | 63 | 14.2 | 64 | 8.4 |
| Flathead catfish | | | 1 | 1.2 | | | | | | | 1 | 0.3 | | | 1 | 0.1 |
| White bass | | | 1 | 1.2 | | | | | | | 1 | 0.3 | | | 1 | 0.1 |
| Green sunfish | 1 | 0.5 | | | 1 | 1.9 | 4 | 3.8 | 23 | 6.8 | 2 | 0.6 | 27 | 6.1 | 29 | 3.8 |
| Orangespotted sunfish | | | | | 1 | 1.9 | | | | | 1 | 0.3 | | | 1 | 0.1 |
| Bluegill | 4 | 2.1 | 6 | 7.0 | 10 | 18.5 | | | 2 | 0.6 | 20 | 6.1 | 2 | 0.5 | 22 | 2.9 |
| White crappie | 68 | 36.2 | 19 | 22.1 | 3 | 5.6 | 25 | 24.0 | 195 | 57.5 | 90 | 27.4 | 220 | 49.7 | 310 | 40.2 |
| Yellow perch | 27 | 14.4 | 1 | 1.2 | 1 | 1.9 | | | | | 29 | 8.8 | | | 29 | 3.8 |
| Sauger | 3 | 1.6 | 1 | 1.2 | | | | | | | 4 | 1.2 | | | 4 | 0.5 |
| Walleye | | | 1 | 1.2 | | | | | | | 1 | 0.3 | | | 1 | 0.1 |
| Freshwater drum | | | 1 | 1.2 | | | | | | | 1 | 0.3 | | | 1 | 0.1 |
| Total | 188 | | 86 | | 54 | | 104 | | 339 | | 328 | | 443 | | 771 | |
| Overnight sets | (13) | | (10) | | (9) | | (9) | | (8) | | (32) | | (17) | | (49) | |

Table 3. Number and percentage composition of adult fish caught with shocker in the study ponds during May and June, 1978

| Species | Pond 1 | | Pond 2 | | Pond 3 | |
|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % |
| Paddlefish | 1 | 1.5 | 1 | 1.3 | 2 | 1.1 |
| Shortnose gar | 1 | 1.5 | 3 | 3.8 | | |
| Gizzard shad | | | 7 | 8.8 | 7 | 3.9 |
| Carp | 24 | 35.3 | 22 | 27.5 | 17 | 51.5 |
| River carpsucker | 10 | 14.7 | 26 | 32.5 | 4 | 12.1 |
| Smallmouth buffalo | 4 | 5.9 | 3 | 3.8 | | |
| Bigmouth buffalo | 3 | 4.4 | 4 | 5.0 | 2 | 6.1 |
| Shorthead redhorse | | | 6 | 7.5 | 1 | 3.0 |
| Black bullhead | 2 | 2.9 | | | 2 | 1.1 |
| Channel catfish | | | 1 | 1.3 | 1 | 3.0 |
| White bass | | | 1 | 1.3 | | |
| Green sunfish | | | | | 2 | 6.1 |
| Bluegill | 6 | 8.8 | 1 | 1.3 | 2 | 6.1 |
| Largemouth bass | 2 | 2.9 | 1 | 1.3 | 1 | 3.0 |
| White crappie | 2 | 2.9 | 1 | 1.3 | | |
| Black crappie | 1 | 1.5 | | | | |
| Yellow perch | 10 | 14.7 | | | | |
| Sauger | | | | | 1 | 3.0 |
| Walleye | 2 | 2.9 | | | | |
| Freshwater drum | | | 3 | 3.8 | 2 | 6.1 |
| Total | 68 | | 80 | | 33 | |
| Effort x 20 min | (5) | | (6) | | (4) | |

ripe. Male carp, river carpsucker, and female bluegill captured in June were running ripe. Other species captured were not running ripe.

Twenty species captured in Pond 2 during May and June included ripe male river carpsucker, carp, and black crappie. Running ripe female bigmouth buffalo, goldeye, carp, bluegill, and black crappie were also captured. Three shortnose gar were observed spawning in shallow water in this pond on May 28.

Samples from Pond 3 contained sixteen species in May and June. Twelve shortnose gar including running ripe males and females were captured in a single overnight trap net set in May. Running ripe male carp and river carpsucker were captured in June.

In Pond 4, only nine species were captured with the trap net during May and June. Shocking was ineffective in this pond. Running ripe fish caught included male carp during May and female green sunfish during June.

Twelve species were captured by trapnet in Pond 5 during May and June. Shocking proved ineffective in this pond. Ripe adults caught included white crappie of both sexes, female green sunfish, and female tadpole madtom.

Many species of stream fishes travel great distances. Funk (1957), in a study of fish movement in Missouri streams, noted that stream fishes are very mobile, especially individuals in unstable habitats. Lambou (1960) reported extensive movement of some species into backwaters of Louisiana, particularly during the spring flood period. Welker (1963) felt that large sauger moved from open oxbow lakes of the Missouri River into the main channel after the fish reached approximately 400 mm TL.

Movement of adult fish between open ponds and the main channel was evidently common. Catfish, river carpsucker, goldeye, shorthead redhorse, and Notropis spp. are typically found in the main channel (Bulkley and Persons 1977, Hey and Baldwin 1977) and were commonly captured in the lacustrine open ponds. Single individuals of American eel and blue catfish, also mobile species, were taken in Pond 2. Fish were occasionally seen swimming through gaps which connected the main channel with open ponds.

Adult fish moved into closed ponds after July 1 when the ponds were connected with the river. An adult goldeye which was marked in Pond 1 was later recaptured in Pond 4. Adult goldeye, river carpsucker, channel catfish, freshwater drum, and Notropis spp. were captured in closed ponds only after the ponds were connected with the river.

The presence of more species in open ponds may be a result of regular winterkills. Open ponds are rapidly repopulated by fish moving in from the main channel but closed ponds are not repopulated except during periods of exceptionally high water levels. The species composition of closed ponds, therefore, tends to become dominated by species such as the black bullhead and fathead minnow, which are tolerant of low dissolved oxygen conditions.

## Young-of-the-Year Catches

Data from Miller tube, tow net, seine, and trapnet catches were examined to determine the relative abundance and species composition of y.o.y. fish in the study ponds. Each gear was both size- and species-selective depending on the mesh size and habitat sampled. Miller tubes and tow nets rarely captured fish larger than 25 mm TL. Miller tubes sampled near the surface of the limnetic zone of the ponds. The tow net, on the other hand, sampled littoral areas as well as the limnetic zone. The seine and trap net sampled littoral areas. Selectivity of each type of collection gear was constant. Therefore, catches in the different ponds were compared by gear type.

Great numbers of small (< 10 mm) larvae in samples indicated that spawning and hatching of many species took place in the backwater ponds. Larval fish densities during June in tow net samples (Figure 3) were more than ten times greater than the densities reported in the main channel drift (Kallemeyn and Novotny 1977, Hey 1979). Hey reported larval densities (no/100 $m^3$) similar to those reported by Kallemeyn and Novotny until the first week of July. During early July, Hey reported densities similar to those found in the backwater ponds. Larval freshwater drum accounted for high densities in the drift during July (Hey 1979). Great numbers of freshwater drum in the drift during early July 1978 were presumably flushed from Lewis and Clark Lake and do not represent main channel reproduction. Walburg (1971) reported that over 1 million freshwater drum larvae were flushed out of Lewis and Clark Lake during a 24-hr period during 1969 and 1970.

The species composition in the ponds also differed from that of the main-channel drift. Centrarchids (sunfish (<u>Lepomis</u> spp.), crappie, and largemouth bass) made up a greater percentage of catches in ponds than in the drift (Figure 4). Freshwater drum, on the other hand, made up a greater percentage of the fish caught in the drift. Shortnose gar, black bullhead, tadpole madtom, and largemouth bass were not reported in the

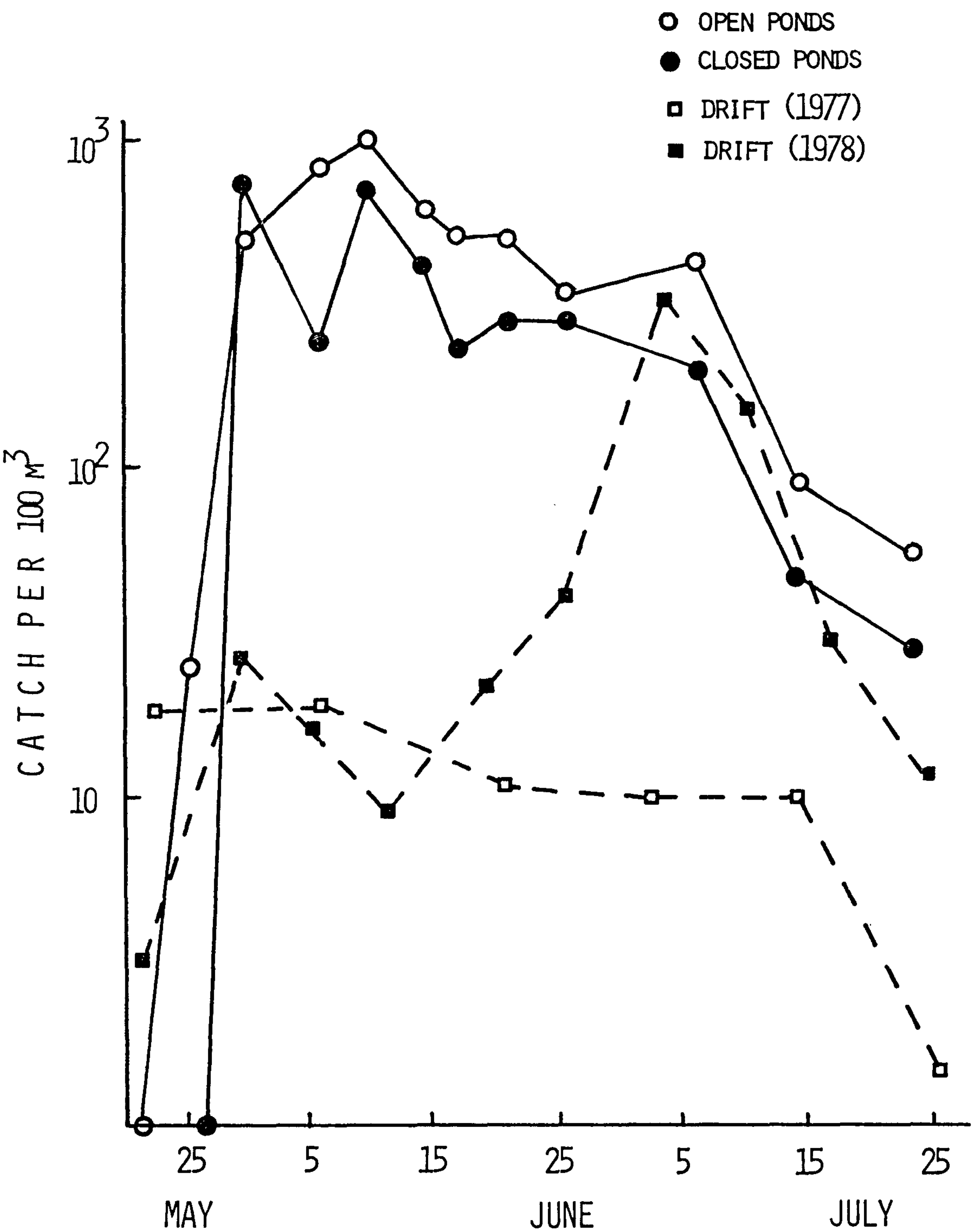



Figure 3. Comparison of mean tow net catch of young-of-the-year fishes per 100 $m^3$ of water filtered in the study ponds and in the main-channel drift (Kallemeyn and Novotny 1977, Hey 1979)

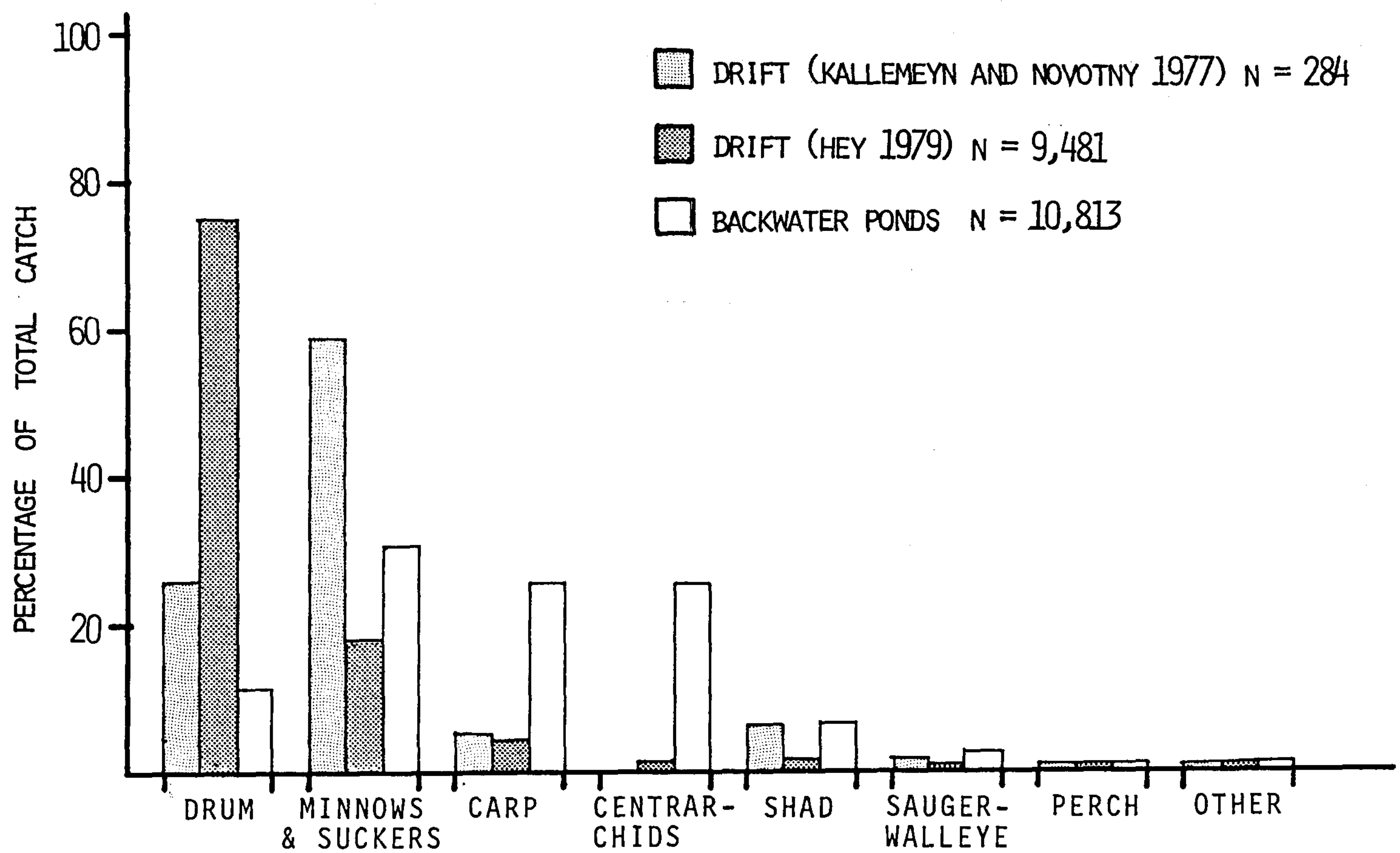



Figure 4. Percentage composition of certain fish taxa captured by tow net in the study ponds and in the main-channel drift

drift by Kallemeyn and Novotny (1977) and Hey (1979).

The greater densities of many fish species in the backwater ponds and the absence of several species from the drift indicate that quiet, off-channel areas serve as the principal spawning areas for many species.

Twenty-five taxa of y.o.y. fish were identified in tow net, Miller, seine, and trap net samples (Table 4). Twenty-four species were captured in open ponds, but only fourteen were taken in closed ponds. The tadpole madtom was the only species of y.o.y. captured exclusively in closed ponds. Several species were captured in closed ponds only after the ponds were connected with the main channel of the river (Table 4).

Tow net catches

There were great variations in tow net catches of y.o.y. within open and closed ponds, but during most of the season, catches per effort were higher in open ponds (Figure 3). Larvae of some species such as largemouth bass and white bass rarely were caught by tow net. Juveniles, however, were common in seine and trap net catches, indicating that the tow net did not adequately sample these tightly schooled species. The tow net sampled both the limnetic and the littoral zones of the study ponds but was relatively ineffective in sampling around logs or along the face of stone dikes and revetments. It is possible that some species, such as the white bass, spent much of their larval stage hiding among the crevices provided by the stone structures. It was assumed that selectivity of the tow net was constant, however, so that catches between ponds could be compared.

Table 4. List of young-of-the-year fishes collected in the study ponds. "X" denotes the presence of a taxonomic group

| Taxonomic group | Open ponds | | | Closed ponds | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Paddlefish | X | | | | |
| Shortnose gar | X | | | X | X |
| Gizzard shad | X | X | X | X | X[a] |
| Goldeye | X | | X | | |
| Carp | X | X | X | X | X |
| Fathead minnow | | X | | X | X |
| Other minnows (Notropis spp.) | X | X | X | | |
| River carpsucker | | | X | | |
| White sucker | | | X | | |
| Blue sucker | X | | X | | |
| Smallmouth buffalo | | X | | | |
| Bigmouth buffalo | X | X | X | X | X |
| Shorthead redhorse | X | | X | | |
| Unidentified suckers | X | X | X | X | X |
| Black bullhead | X | X | | X | X |
| Channel catfish | | X | X | X[a] | |
| Tadpole madtom | | | | X | X |
| Flathead catfish | | X | | | |
| White bass | X | X | X | X[a] | |
| Sunfish | X | X | X | X | X |
| Largemouth bass | X | X | X | X | X |
| Crappie | X | X | X | X | X |
| Johnny darter | X | X | X | | |
| Yellow perch | X | X | X | | X |
| Sauger-walleye | X | X | X | | |
| Freshwater drum | X | X | X | X[a] | |

[a] Present only after the pond was connected with the main channel.

Over 90% of the y.o.y. fish captured with tow net in the study ponds were carp, suckers, minnows, sunfish, crappie, and drum (Table 5). Carp was the most abundant species captured and comprised 24.5% of the total catch, ranging from 64.2% of the catch in Pond 5 and from 7-17% of the catch in the other 4 ponds. Suckers were the second most abundant group captured representing about 30% of the catch in open ponds but less than 1% in closed ponds. There were great variations in catches of sunfish within open and closed ponds. Sunfish were the most numerous group captured in open Ponds 1 and 2 but represented less than 1% of the catch in Pond 3. Sunfish averaged 12.3% of the catch in closed ponds and 16.0% in open ponds. Crappie catches also showed great variation within open and closed ponds. They were the most numerous species captured in Pond 4 (44.8%) and the second most abundant species in Pond 1 (19.2%) but made up less than 7% of the catch in each of the other ponds. Sunfish and crappie, combined, was the most abundant group captured in Ponds 1, 2, and 4 and the second most abundant group from Pond 5. Gizzard shad comprised less than 2% of the catch in all ponds, except Pond 2 where they made up 23.4% of the catch. Freshwater drum averaged 13.4% of the catch in open ponds. A single sample of 200 drum was collected in Pond 4 after the pond was connected with the main channel. Drum were not captured in Pond 5. Minnows were represented by the fathead minnow in the closed ponds and by several species of shiners (Notropis spp.) in the open ponds. Minnows made up less than 6% of the catch in Ponds 1 and 2 and approximately 15% of the total catch in Ponds 3, 4, and 5. Sauger-walleye represented less than 3% of the total catch in open ponds and were not captured in closed ponds.

Table 5. Number and percentage composition of young-of-the-year fishes captured with tow net in the study ponds, May 12 - July 23, 1978

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| Taxonomic group | Open ponds | | | | | | Closed ponds | | | | Open ponds | | Closed ponds | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | | | | | | |
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Paddlefish | 1 | 0.1 | | | | | | | | | 1 | t[a] | | | 1 | t |
| Shortnose gar | 3 | 0.2 | | | | | 1 | 0.1 | | | 3 | t | 1 | t | 4 | t |
| Gizzard shad | 6 | 0.5 | 618 | 23.4 | 24 | 0.8 | 20 | 1.6 | | | 648 | 9.1 | 20 | 0.5 | 668 | 6.2 |
| Minnows | 40 | 3.0 | 151 | 5.7 | 482 | 15.0 | 181 | 14.7 | 348 | 14.2 | 673 | 9.4 | 529 | 14.4 | 1202 | 11.1 |
| Carp | 207 | 15.6 | 446 | 17.7 | 234 | 7.3 | 194 | 15.8 | 1568 | 64.2 | 887 | 12.4 | 1762 | 48.0 | 2649 | 24.5 |
| Suckers | 162 | 12.2 | 263 | 10.0 | 1683 | 52.6 | 17 | 1.4 | | | 2108 | 29.5 | 17 | 0.5 | 2125 | 19.7 |
| Blue sucker | 1 | 0.1 | | | 5 | 0.1 | | | | | 6 | 0.1 | | | 6 | 0.1 |
| Channel catfish | | | 1 | t | | | | | | | 1 | t | | | 1 | t |
| Black bullhead | 1 | 0.1 | | | | | 3 | 0.2 | 65 | 2.7 | 1 | t | 68 | 1.9 | 69 | 0.6 |
| Tadpole madtom | | | | | | | 4 | 0.3 | 4 | 0.2 | | | 8 | 0.2 | 8 | 0.1 |
| White bass | | | | | 1 | t | 1 | t | | | 1 | t | 1 | t | 2 | t |
| Sunfish | 405 | 30.7 | 712 | 27.0 | 24 | 0.8 | 58 | 4.7 | 393 | 16.1 | 1141 | 16.0 | 451 | 12.3 | 1592 | 14.7 |
| Largemouth bass | 24 | 1.8 | 18 | 0.7 | 2 | t | | | | | 44 | 0.6 | | | 44 | 0.4 |
| Crappie | 254 | 19.2 | 168 | 6.4 | 5 | t | 550 | 44.8 | 64 | 2.6 | 427 | 6.0 | 614 | 16.7 | 1041 | 9.6 |
| Johnny darter | 7 | 0.5 | 4 | 0.1 | 10 | 0.3 | | | | | 21 | 0.3 | | | 21 | 0.2 |
| Yellow perch | 9 | 0.7 | 3 | 0.1 | 22 | 0.7 | | | 1 | t | 34 | 0.5 | 1 | t | 35 | 0.3 |
| Sauger-walleye | 19 | 1.4 | 11 | 0.4 | 154 | 4.8 | | | | | 184 | 2.6 | | | 184 | 1.7 |
| Freshwater drum | 184 | 13.9 | 223 | 8.5 | 550 | 17.2 | 200 | 16.3 | | | 957 | 13.4 | 200 | 5.5 | 1157 | 10.7 |
| Unidentified | | | | | 4 | t | | | | | 4 | t | | | 4 | t |
| Total number | 1323 | | 2618 | | 3200 | | 1229 | | 2443 | | 7141 | | 3672 | | 10813 | |

[a] t = less than 0.1.

Relative abundance of each species was examined more closely by comparing catch per effort by gear between open and closed ponds for a 10-week period. Mean seasonal catches of gizzard shad varied greatly between ponds and ranged from 0 to 101 per 100 $m^3$ (Table 6). The catch in open Pond 2 far exceeded those from other ponds. No shad were captured by tow net in closed Pond 5, and few were taken in Pond 4. Larvae usually appeared in tow net samples in all ponds during late May or the first week of June, where present, and the maximum catches occurred during the middle of June (Figure B.1). Shad larvae less than 15 mm TL were captured until the end of sampling in open ponds, but, in Pond 4, none were captured after June.

Tow net catches of carp in Pond 5 averaged 249 fish per 100 $m^3$ and were much greater than samples in other ponds. Carp were caught until mid July in all ponds except Pond 5, where they were last taken in tow net samples on June 28 (Figure B.2).

Mean seasonal catch of suckers varied from 4 to 275 fish per 100 $m^3$ with greatest catches occurring in open ponds. No larval suckers were captured by tow net in Pond 5 although y.o.y. bigmouth buffalo were later captured in seines. Peak catches of suckers occurred during late May and early June in open ponds and during mid July in closed Pond 4 (Figure B.3).

The greatest mean catch of minnows took place in Pond 3. There were great variations in catches between ponds but the mean seasonal catches in open and closed ponds were similar. Minnows were captured through late July in all ponds except Pond 5 where none were captured after July 7 (Figure B.4).

Table 6. Mean tow net catch per 100 $m^3$ of most abundant species in the study ponds, May 12-July 23, 1978

| Taxonomic group | Open ponds | | | Closed ponds | | Average | | Total |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Open | Closed | |
| Gizzard shad | 1 | 101 | 10 | 5 | 0 | 37 | 3 | 23 |
| Carp | 34 | 76 | 38 | 26 | 249 | 49 | 138 | 124 |
| Minnows | 7 | 25 | 78 | 22 | 44 | 37 | 33 | 35 |
| Suckers | 31 | 43 | 275 | 4 | 0 | 116 | 2 | 59 |
| Sunfish | 89 | 116 | 3 | 8 | 63 | 69 | 36 | 56 |
| Crappie | 42 | 28 | 1 | 65 | 8 | 24 | 37 | 29 |
| Sauger-walleye | 3 | 2 | 25 | 0 | 0 | 10 | 0 | 6 |
| Freshwater drum | 30 | 36 | 88 | 26 | 0 | 51 | 13 | 36 |
| Total | 237 | 427 | 518 | 156 | 364 | 393 | 262 | 368 |

Catch per effort of sunfish in tow net samples varied from a mean of 3.0 in Pond 3 to 116 per 100 $m^3$ in Pond 2. Peak catches occurred during the second and third weeks of June in all ponds (Figure B.5).

Crappie were captured by tow net in all ponds but, like sunfish, in much lower abundance in Pond 3. They first appeared in catches during the last week of May in the open ponds and during the first and second weeks of June in the closed ponds (Figure B.6).

Sauger and walleye were captured by tow net only in the open ponds. Catch was greatest in Pond 3 during early June; mean seasonal catch per effort was 25 fish per 100 $m^3$. Curves of seasonal catch per effort for Ponds 1 and 2 were difficult to evaluate because of the low numbers of fish captured (Figure B.7).

Mean catch per effort of freshwater drum was 30, 36, and 88 fish per 100 $m^3$ at Ponds 1, 2, and 3, respectively (Table 6). Larvae of this species were not captured in Pond 5 and on only one occasion in Pond 4 (Figure B.8).

Seine catches

Seining was possible only in the littoral zone and thus was selective for species utilizing that area. It is assumed that certain species were able to avoid the seine, and that their ability to escape capture increased as the fish grew. The distributional or schooling behavior of some y.o.y. such as gizzard shad, largemouth bass, sunfish, and crappie may also have affected the catches of these fish, but it was assumed that these factors were equal in all ponds so that catches in the different ponds could be accurately compared.

Carp, crappie, minnows, gizzard shad, and black bullheads were the most numerous y.o.y. captured in seine hauls. No other single species accounted for more than 3% of the total seine catch of y.o.y. fishes from the five ponds (Table 7). Crappie, minnows, and gizzard shad accounted for over 85% of the catch in the open ponds, whereas crappie, minnows, and carp made up about 85% of the catch from closed ponds. Carp accounted for only 1.0% of the catch in the open ponds but over 50% of the catch in closed ponds. Gizzard shad, on the other hand, made up 22% of the catch in open ponds and only 0.2% of the catch in closed ponds.

Species common in open ponds but absent from closed ponds included white bass, yellow perch, sauger, walleye, and freshwater drum. Other species captured rarely in open ponds but not in closed ponds included goldeye, blue sucker, shorthead redhorse, channel catfish, and flathead catfish.

Gizzard shad was the only species present in all ponds that was captured in greater numbers per effort in open ponds than in closed ponds (Table 8). Seine catches of the densely schooling y.o.y. shad varied greatly during the season and within ponds. They first appeared in samples during mid June and early July in open ponds but not until the second week of July in closed Ponds 4 and 5 (Figure B.1).

Carp seemed to be especially vulnerable to capture with the seine. Samples of over 500 fish per 100 $m^2$ were taken in Pond 5. The seasonal mean catch per effort of carp was much greater in closed ponds. They appeared in the catch the first date that Pond 5 was sampled (June 4) but not until the second week of June in other ponds (Figure B.2).

Table 7. Number and percentage composition of young-of-the-year fishes captured with seine in the study ponds, May 12 - August 4, 1978

| Taxonomic group | Open ponds | | | | | | Closed ponds | | | | Open ponds | | Closed ponds | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | No. | % | No. | % | No. | % |
| | No. | % | No. | % | No. | % | No. | % | No. | % | | | | | | |
| Shortnose gar | 6 | 1.8 | | | | | 6 | 0.5 | | | 6 | 0.4 | 6 | 0.1 | 12 | 0.2 |
| Gizzard shad | 5 | 1.5 | 243 | 38.6 | 51 | 13.6 | 3 | 0.2 | 5 | 0.2 | 299 | 22.4 | 8 | 0.2 | 307 | 5.4 |
| Goldeye | 1 | 0.3 | | | 1 | 0.3 | | | | | 2 | 0.1 | | | 2 | t[a] |
| Minnows | 100 | 30.0 | 139 | 22.1 | 267 | 71.4 | 47 | 3.9 | 348 | 11.0 | 506 | 37.9 | 395 | 9.0 | 901 | 15.8 |
| Carp | 3 | 0.9 | 9 | 1.4 | 1 | 0.3 | 207 | 17.2 | 2080 | 65.8 | 13 | 1.0 | 2287 | 52.4 | 2300 | 40.3 |
| Suckers | 9 | 2.7 | 36 | 5.7 | 16 | 4.5 | 34 | 2.8 | 7 | 0.2 | 61 | 4.6 | 41 | 0.9 | 102 | 1.8 |
| Blue sucker | | | | | 9 | 2.4 | | | | | 9 | 0.7 | | | 9 | 0.2 |
| White sucker | | | | | 2 | 0.6 | | | | | 2 | 0.1 | | | 2 | t |
| Smallmouth buffalo | | | 2 | 0.4 | | | | | | | 2 | 0.1 | | | 2 | t |
| Bigmouth buffalo | 8 | 2.4 | 34 | 5.3 | 4 | 1.2 | 34 | 2.8 | 7 | 0.2 | 46 | 3.4 | 41 | 0.9 | 87 | 1.5 |
| Shorthead redhorse | 1 | 0.3 | | | 1 | 0.3 | | | | | 2 | 0.1 | | | 2 | t |
| Channel catfish | | | | | 2 | 0.5 | | | | | 2 | 0.1 | | | 2 | t |
| Flathead catfish | | | 1 | 0.2 | | | | | | | 1 | 0.1 | | | 1 | t |
| Black bullhead | | | 1 | 0.2 | | | 10 | 0.8 | 224 | 7.1 | 1 | 0.1 | 234 | 5.4 | 235 | 4.1 |
| Tadpole madtom | | | | | | | 1 | 0.1 | | | | | 1 | t | 1 | t |
| White bass | 5 | 1.5 | 7 | 1.1 | 4 | 1.1 | | | | | 16 | 1.2 | | | 16 | 0.3 |
| Sunfish | 8 | 2.4 | 5 | 0.8 | 14 | 3.7 | 2 | 0.2 | 130 | 4.1 | 27 | 2.0 | 132 | 3.0 | 159 | 2.8 |
| Largemouth bass | 9 | 2.7 | 20 | 3.2 | 5 | 1.3 | 50 | 4.2 | 4 | 0.1 | 34 | 2.5 | 54 | 1.2 | 88 | 1.5 |
| Crappie | 187 | 56.2 | 154 | 24.5 | 10 | 2.7 | 844 | 70.1 | 365 | 11.5 | 351 | 26.3 | 1209 | 27.7 | 1560 | 27.4 |
| Yellow perch | | | 1 | 0.2 | | | | | | | 1 | 0.1 | | | 1 | t |
| Sauger-walleye | | | 9 | 1.4 | 2 | 0.5 | | | | | 11 | 0.8 | | | 11 | 0.2 |
| Freshwater drum | | | 4 | 0.6 | | | | | | | 4 | 0.3 | | | 4 | 0.1 |
| Total | 333 | | 629 | | 373 | | 1204 | | 3163 | | 1335 | | 4367 | | 5702 | |

[a] t = less than 0.1.

Dense schools of y.o.y black bullheads were frequently seen in Ponds 4 and 5 but not in other ponds. The mean seasonal catches of this species varied from 0.03 in Pond 2 where a single fish was captured to 19.0 fish per 100 $m^2$ in Pond 5 where 224 fish were captured (Table 8).

Sunfish were captured with the seine in all ponds. Mean seasonal catches were less than 1.0 in all ponds except Pond 5 where the mean seasonal catch was 10.8 fish per 100 $m^2$. Sunfish first appeared in the seine catch during the third week of June in Pond 5 and during the first and second weeks of July in other ponds (Figure B.5).

Crappie were also captured in all ponds but were more numerous in catches from closed ponds (Table 7). The mean seasonal average was 5.6 in the open ponds compared to 43.8 fish per 100 $m^2$ in the closed ponds. Crappie first appeared in the seine catch during the third week of June in all ponds (Figure B.6).

Sauger-walleye were not very susceptible to capture with the seine. Mean catches of 0.4 and 0.1 fish per 100 $m^2$ were made in open Ponds 2 and 3 (Table 8).

Trap net catches

Trap nets tended to capture larger individuals than did tow nets, but they also showed great variation among open and closed ponds. The trap net was probably the most selective gear used; some species avoided the net or were not captured because of the relatively large mesh size of the gear (1.3 cm).

Young-of-the-year carp were captured in trap nets three weeks earlier in Pond 5 than in other ponds; the 207 y.o.y. carp captured in

Table 8. Mean seine catch per 100 $m^2$ of most abundant species in the study ponds, May 12-August 4, 1978

| Taxonomic group | Open ponds | | | Closed ponds | | Average | | Total |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Open | Closed | |
| Gizzard shad | 0.3 | 9.9 | 2.8 | 0.2 | 0.4 | 4.3 | 0.3 | 2.7 |
| Carp | 0.2 | 0.2 | | 14.0 | 303.0 | 0.1 | 159.0 | 63.5 |
| Minnows | 6.7 | 8.2 | 15.7 | 3.1 | 75.1 | 10.2 | 39.1 | 21.8 |
| Suckers | 0.4 | 1.6 | 0.7 | 2.3 | 0.6 | 0.8 | 1.5 | 1.1 |
| Bigmouth buffalo | 0.4 | 1.5 | 0.3 | 2.3 | 0.6 | 0.7 | 1.5 | 1.0 |
| Smallmouth buffalo | | 0.1 | | | | t[a] | | t |
| Blue sucker | | | 0.3 | | | 0.1 | | t |
| White sucker | | | 0.1 | | | t | | t |
| Shorthead redhorse | t | | t | | | t | | t |
| Black bullhead | | t | | 0.7 | 19.0 | t | 1.9 | 3.9 |
| Sunfish | 0.5 | 0.2 | 0.4 | 0.1 | 10.8 | 0.4 | 5.5 | 2.5 |
| Largemouth bass | 0.6 | 0.6 | 0.2 | 3.3 | 0.3 | 0.5 | 1.5 | 1.0 |
| Crappie | 10.1 | 6.4 | 0.4 | 56.3 | 31.3 | 5.6 | 43.8 | 20.9 |
| Sauger-walleye | | 0.4 | 0.1 | | | 0.3 | | 0.1 |
| Total | 18.8 | 27.5 | 20.3 | 80.0 | 440.5 | 22.2 | 260.6 | 118.5 |

[a] t = less than 0.1.

Pond 5 before July 6 were not included in the comparisons of catches. Young-of-the-year of fourteen species of fish comprising 600 individuals were captured in trap nets between July 6 and August 4, 1978 (Table 9). Species absent from trap net catches in closed ponds but present in open ponds included gizzard shad, smallmouth buffalo, river carpsucker, bluegill, walleye, and freshwater drum. Yellow perch were caught in closed Pond 5 and not in open ponds although they were taken by other methods in open ponds. One channel catfish and a single white bass were captured in Pond 4 after the pond was connected with the main channel of the river.

Black bullheads and carp made up over 82% of the catch in closed ponds but less than 13% of the catch in open ponds. Black bullheads were the most abundant species captured, but 92% of all bullheads were taken in Pond 5. No bullheads were collected in Ponds 2 or 3. Crappie were the second most abundant species captured and were collected in all ponds. In Ponds 1, 2, 3, and 4, they comprised about 50% of the catches but made up less than 10% of the catch in Pond 5. Greater numbers of fish were captured in closed ponds ($X^2 = 44.9$, $P < 0.05$) than in open ponds because of large catches in Pond 5.

## Zooplankton

Zooplankton is of ecological importance since it is a basic part of the food chain of many fish and in some instances may be the primary factor involved in survival of y.o.y. and fish production in ponds (Smith and Swingle 1939, Hunter 1975). The abundance of planktonic organisms was determined from Van Dorn bottle collections obtained on the same night as larval fish samples. Catches were expressed as the number of organisms

Table 9. Number and percentage composition of young-of-the-year fishes captured with trap net in the study ponds, July 6 - August 4, 1978

| Taxonomic group | Open ponds | | | | | | Closed ponds | | | | Open ponds | | Closed ponds | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | | | | | | |
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Gizzard shad | | | 2 | 2.3 | 3 | 9.4 | | | | | 5 | 2.7 | | | 5 | 0.8 |
| Carp | 4 | 6.1 | 2 | 2.3 | 6 | 18.8 | 8 | 19.0 | 118 | 31.6 | 12 | 6.5 | 126 | 30.3 | 138 | 23.0 |
| Suckers | 6 | 9.2 | 4 | 4.7 | 2 | 6.3 | 3 | 7.1 | 8 | 2.1 | 12 | 6.5 | 11 | 2.6 | 23 | 3.8 |
| Bigmouth buffalo | 6 | 9.2 | 3 | 3.5 | 1 | 3.1 | 3 | 7.1 | 8 | 2.1 | 10 | 5.4 | 11 | 2.6 | 21 | 3.5 |
| Smallmouth buffalo | | | 1 | 1.2 | | | | | | | 1 | 0.5 | | | 1 | 0.2 |
| River carpsucker | | | | | 1 | 3.1 | | | | | 1 | 0.5 | | | 1 | 0.2 |
| Channel catfish | | | | | | | 1 | 2.4 | | | | | 1 | 0.2 | 1 | 0.2 |
| Black bullhead | 12 | 8.5 | | | | | 7 | 16.7 | 211 | 56.5 | 12 | 6.5 | 218 | 52.4 | 230 | 38.3 |
| White bass | 12 | 18.5 | 1 | 1.2 | | | 1 | 2.4 | | | 13 | 7.1 | 1 | 0.2 | 14 | 2.3 |
| Bluegill | | | 2 | 2.4 | | | | | | | 2 | 1.1 | | | 2 | 0.3 |
| Crappie | 32 | 49.2 | 74 | 86.0 | 17 | 53.1 | 21 | 50.0 | 24 | 6.4 | 123 | 66.8 | 45 | 10.8 | 168 | 28.0 |
| Largemouth bass | | | | | 2 | 6.3 | 1 | 2.4 | | | 2 | 1.1 | 1 | 0.2 | 3 | 0.5 |
| Yellow perch | | | | | | | | | 13 | 3.5 | | | 13 | 3.1 | 13 | 2.2 |
| Walleye | | | 1 | 1.2 | 1 | 3.1 | | | | | 2 | 1.1 | | | 2 | 0.3 |
| Freshwater drum | | | | | 1 | 3.1 | | | | | 1 | 0.5 | | | 1 | 0.2 |
| Total | 66 | | 86 | | 32 | | 42 | | 374 | | 184 | | 416 | | 600 | |

per 100 liters of water sampled. Catches of most organisms varied greatly during the season, as is typical for most shallow ponds (Hutchinson 1967).

Most zooplankton contained in a stream must be produced in adjacent quiet water areas or elsewhere in the drainage and, subsequently, supplied to the river flow (Hynes 1970). Backwater ponds evidently serve as major sites of zooplankton production in the channelized Missouri River. Zooplankton densities in the study ponds in 1978 averaged more than 25 times greater than the densities reported in the main channel drift by Kallemeyn and Novotny (1977). Copepod nauplii were more than 500 times more abundant in pond samples than in main channel drift samples (Table 10). Annual differences in production would not be expected to reach this magnitude. Much of the zooplankton in the drift was probably contributed from Lewis and Clark Lake (Cowell 1967) and from backwater areas of the unchannelized river (Kallemeyn and Novotny 1977).

Rotifers were by far the most numerous organisms captured in backwater ponds and averaged over 72% of the catch (Table 11). Copepods were the second most abundant group and made up 22.4% of the catch. Copepod nauplii were abundant and comprised 70.6% of the total catch of copepods. Cyclopoid, calanoid, and parasitic copepods each represented less than 5% of the total catch. <u>Daphnia</u>, <u>Bosmina</u>, and <u>Leptodora</u> were the major representatives of the Cladocera which made up 5.8% of the total catch by numbers of planktonic organisms. This pattern of percentage composition was observed in all ponds for the period June 4 to July 23 although variations on individual sampling dates were common.

The mean number of organisms counted in collections from the ponds between June 4 and July 23 were compared by chi square tests. Greater

Table 10. Mean number of zooplankton per $m^3$ captured in the study ponds and in the main channel drift (Kallemeyn and Novotny 1977)

| Species | Drift | Ponds |
|---|---|---|
| Calanoid copepods | 2,104 | 10,073 |
| Cyclopoid copepods | 1,669 | 25,520 |
| Copepod nauplii | 171 | 91,550 |
| Daphnia | 2,106 | 9,100 |
| Other cladocera | 34 | 19,740 |
| Total | 6,084 | 155,983[a] |

[a] Total does not include 419,060 Rotifera. Kallemeyn and Novotny (1977) did not record Rotifera but Hey and Baldwin (1977) reported numbers of about $130/m^3$.

Table 11. Mean number of zooplankton per 100 liters of water and percentage of total sample from the study ponds, June 4 - July 23, 1978

| Taxonomic group | Open ponds | | | | | | Closed ponds | | | | Open ponds | | Closed ponds | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | | | | | | |
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Rotifera | 56977 | 78.0 | 44222 | 77.5 | 11500 | 60.0 | 61942 | 79.0 | 30549 | 57.1 | 37566 | 75.5 | 30549 | 57.1 | 41906 | 72.4 |
| _Leptodora_ | 1191 | 1.6 | 175 | 0.3 | 83 | 0.4 | 2564 | 3.3 | 299 | 0.6 | 483 | 1.0 | 1432 | 2.2 | 958 | 1.7 |
| _Diaphanosoma_ | 820 | 1.1 | 474 | 0.8 | 46 | 0.2 | | | 504 | 0.9 | 447 | 0.9 | 252 | 0.4 | 350 | 0.6 |
| _Daphnia_ | 582 | 0.8 | 340 | 0.6 | 491 | 2.6 | 1225 | 1.6 | 1472 | 2.8 | 471 | 2.6 | 1349 | 2.0 | 910 | 1.6 |
| _Ceriodaphnia_ | | | | | 111 | 0.6 | | | 124 | 0.2 | 37 | 0.1 | 62 | 0.1 | 50 | 0.1 |
| _Moina_ | | | 30 | 0.1 | 56 | 0.3 | 308 | 0.4 | 247 | 0.5 | 29 | 0.1 | 278 | 0.4 | 154 | 0.3 |
| _Bosmina_ | 79 | 0.1 | 30 | 0.1 | 630 | 3.3 | 103 | 0.1 | 432 | 0.8 | 246 | 0.5 | 268 | 0.4 | 257 | 0.4 |
| _Pleuroxus_ | 291 | 0.4 | 133 | 0.2 | 101 | 0.5 | 196 | 0.2 | 93 | 0.2 | 175 | 0.4 | 145 | 0.2 | 160 | 0.3 |
| Other Cladocera | 13 | t[a] | 185 | 0.3 | 37 | 0.2 | 21 | t | | | 78 | 0.2 | 11 | t | 45 | 0.1 |
| Total Cladocera | 2976 | 4.1 | 1367 | 2.4 | 1555 | 8.1 | 4417 | 5.6 | 3171 | 5.9 | 1966 | 4.0 | 3797 | 5.8 | 2884 | 5.0 |
| Ostracoda | 26 | t | 61 | 0.1 | 9 | t | 31 | t | 206 | 0.4 | 32 | 0.3 | 119 | 0.2 | 76 | 0.1 |
| Calanoid copepods | 649 | 0.9 | 360 | 0.6 | 686 | 3.6 | 1524 | 1.9 | 1637 | 3.0 | 565 | 1.1 | 1581 | 2.4 | 1073 | 1.9 |
| Cyclopoid copepods | 2899 | 4.0 | 2780 | 4.9 | 1845 | 9.6 | 1895 | 2.4 | 3294 | 6.2 | 2508 | 5.0 | 2595 | 3.9 | 2552 | 4.4 |
| Parasitic copepods | 26 | t | 154 | 0.3 | 120 | 0.6 | | | 566 | 1.1 | 100 | 0.2 | 283 | 0.4 | 192 | 0.3 |
| Copepod nauplii | 9518 | 13.0 | 8082 | 14.2 | 3382 | 17.7 | 8607 | 11.0 | 14024 | 26.2 | 6994 | 14.1 | 11316 | 17.2 | 9155 | 15.8 |
| Total copepods | 13092 | 17.9 | 11376 | 19.9 | 6033 | 31.5 | 12026 | 15.3 | 19521 | 36.5 | 10167 | 20.4 | 15775 | 23.9 | 12972 | 22.4 |
| Chironomidae | | | | | 56 | 0.3 | | | 62 | 0.1 | 19 | t | 31 | t | 25 | t |
| Total | 73075 | | 57031 | | 19154 | | 78416 | | 53510 | | 49753 | | 65968 | | 57860 | |

[a] t = less than 0.1.

numbers of rotifers were counted in samples from open ponds ($X^2 = 3.96$, $P < 0.05$). Mean counts of other organisms were not significantly different ($P > 0.05$) among open and closed ponds. Comparing the ponds individually, samples from Pond 4 contained the most rotifers ($X^2 = 45.12$, $P < 0.01$) and Pond 3 had the fewest ($X^2 = 71.86$, $P < 0.01$). Pond 3 also had the fewest copepod nauplii ($X^2 = 11.28$, $P < 0.01$) whereas Pond 5 had the most ($X^2 = 12.51$, $P < 0.01$). Twelve of the 15 taxa identified were more numerous in samples from closed ponds although the differences were not found to be significant ($P > 0.05$) by the chi square test.

Seasonal variations in catch per effort of the most commonly captured classes were examined for trends in abundance (Figures C.1-C.6). Comparison of relative abundance of plankton as reflected by catch per effort data between open and closed ponds revealed few differences in seasonal trends of abundance. Considerable variation in catch was evident but magnitude of catch in open and closed was surprisingly similar. Data from tow net and Miller samples suggested, however, that zooplankton was more abundant in closed ponds. The volume of zooplankton filtered in Miller samples from closed ponds frequently exceeded 200 ml whereas in open ponds the volume rarely exceeded 100 ml.

## Food Habits

An adequate supply of food for larval fish after they have absorbed their yolk sac and begun feeding is essential, or high mortality will occur (Hjort 1926, Marr 1956). Food of the right kind as well as quantity is also important in determining growth rates of y.o.y. fish.

Large numbers of y.o.y. carp, sunfish (Lepomis spp.), and crappie were captured in all ponds through most of the sampling period. Hence, these taxa provided information on diet and amount of stomach contents in open and closed ponds.

## Carp

Stomach contents of 352 y.o.y. carp collected from the study ponds between May and August were examined. Fifty-seven stomachs contained no food and 20 fish still had yolk sac material present. Fish ranged in size from 5 to 33 mm TL. Cladocerans and copepods were the major groups of food organisms ingested, and constituted 88% of the total number of food items found in stomachs (Table 12).

Ninety-nine percent of the copepods ingested by y.o.y. carp were cyclopoid copepods. Calanoid copepods and unidentified copepod nauplii were abundant in the plankton samples, but made up a very minor portion of the total diet. Rotifers, also abundant in plankton samples, constituted less than 1% of the total food items found in stomachs of y.o.y. carp.

Chydorus was the principal cladoceran consumed. Other Cladocera ingested in smaller quantities were Pleuroxus, Daphnia, Alona, and Ceriodaphnia. Unidentified cladocerans or cladocerans too mutilated to identify accounted for 20.1% of the total number of Cladocera found in carp stomachs.

The number of empty carp stomachs in open and closed ponds was relatively similar (Table 12). Most of the empty stomachs were from larvae less than 10 mm TL. Mean length of y.o.y. carp examined in open

Table 12. Mean number of food organisms per stomach of larval carp and percentage of total stomach contents, May 12-July 23, 1978

| | Open ponds | | Closed ponds | | Total | |
|---|---|---|---|---|---|---|
| Number of stomachs | n = 203 (37)[a] | | n = 149 (21) | | n = 352 (57) | |
| Mean total length | TL = 9.1 | | TL = 13.2 | | TL = 10.8 | |
| Organism | No. | % | No. | % | No. | % |
| Rotifera | t[b] | 1.1 | t | 0.1 | t | 0.4 |
| Leptodora | t | 0.3 | 0.1 | 1.0 | 0.1 | 0.8 |
| Daphnia | 0.1 | 2.1 | 1.5 | 10.3 | 0.7 | 7.8 |
| Ceriodaphnia | t | 0.9 | 0.2 | 1.4 | 0.1 | 1.3 |
| Bosmina | 0.3 | 6.3 | 0.5 | 0.3 | 0.2 | 2.2 |
| Pleuroxus | 0.1 | 2.4 | 1.3 | 9.1 | 0.6 | 7.0 |
| Chydorus | 1.1 | 23.1 | 1.2 | 8.2 | 1.1 | 12.8 |
| Alona | | | 0.5 | 3.1 | 0.2 | 2.1 |
| Simocephalus | 0.1 | 2.1 | 0.1 | 0.5 | 0.1 | 1.0 |
| Unidentified Cladocera | 0.1 | 2.7 | 1.7 | 11.7 | 0.8 | 8.9 |
| Total Cladocera | 1.9 | 39.9 | 6.6 | 45.6 | 3.9 | 43.8 |
| Ostracoda | t | 0.6 | 0.5 | 3.6 | 0.2 | 2.7 |
| Calanoid copepods | t | 0.2 | 0.1 | 0.6 | t | 0.5 |
| Cyclopoid copepods | 2.7 | 56.4 | 5.5 | 37.9 | 3.9 | 43.7 |
| Copepod nauplii | | | 0.1 | 0.4 | t | 0.3 |
| Total Copepoda | 2.7 | 56.6 | 5.6 | 38.6 | 3.9 | 44.2 |
| Tendipedidae larvae | 0.1 | 1.5 | 1.5 | 10.5 | 0.7 | 7.7 |
| Tendipedidae pupa | | | 0.1 | 0.5 | t | 0.3 |
| Insect | t | 0.1 | 0.1 | 0.7 | t | 0.5 |
| Other | t | 0.7 | 0.6 | 4.4 | 0.3 | 3.2 |
| Total | 4.8 | | 14.5 | | 8.9 | |

[a] Number of empty stomachs in parentheses.

[b] t = less than 0.1.

ponds was 9.1 mm vs 13.2 mm in closed ponds but this difference was not considered important in comparing mean numbers of organisms in stomach contents among open and closed ponds.

Carp from closed ponds had on the average about three times as many food items per stomach as carp from open ponds. All organisms except Bosmina were found in greater numbers in stomachs of carp from closed ponds than from open ponds.

The percentage composition of the two dominant food groups, Cladocera and copepods, was similar in open and closed ponds. The most abundant cladocerans in carp stomachs from open ponds were Chydorus and Bosmina, whereas in closed ponds Daphnia, Pleuroxus, Chydorus, and unidentified cladocerans were about equally abundant. Cyclopoid copepods were the most abundant group of copepod consumed in both open and closed ponds. Unidentified copepod nauplii were rarely encountered in carp stomachs from closed ponds and were absent in stomachs examined from open ponds. Additional items found in stomachs from closed ponds but not from open ponds included Alona and Tendipedidae pupae, neither of which was numerically an important food item in closed ponds. Tendipedidae larvae were more numerous in stomachs from closed ponds than from open ponds, making up 10.5% and 1.5% of the totals, respectively.

Sunfish

Large numbers of y.o.y. sunfish (Lepomis spp.) captured in the study ponds also provided information on food habits. Stomach contents of 268 y.o.y. sunfish collected from the study ponds during June and July were examined. Ninety-five stomachs contained no food and one fish still had yolk sac material present. Fish ranged in size from 5 to 22 mm TL. Cladocerans and copepods were the major groups of food organisms ingested and constituted 90% of the total number of food items found in stomachs (Table 13).

Seventy-six percent of the copepods ingested were cyclopoid copepods. Chydorus was the principal cladoceran consumed. Other Cladocera ingested in smaller quantities were Bosmina, Pleuroxus, Ceriodaphnia, Daphnia, and Leptodora. Unidentified cladocerans or cladocerans too mutilated to identify accounted for 16% of the total numbers of cladocera found in sunfish stomachs.

Forty-six percent of stomachs examined from open ponds were empty whereas, in closed ponds, only 19% of stomachs examined were empty. Most empty stomachs were from larvae less than 10 mm TL. Sunfish examined from closed ponds averaged slightly larger than sunfish from open ponds, but this difference was not considered significant in comparing mean numbers of organisms in stomach contents among open and closed ponds.

Sunfish from closed ponds had on the average 4.7 times as many food items per stomach as sunfish from open ponds. All organisms except Bosmina and Chydorus were found in greater numbers in stomachs of sunfish from closed ponds than from open ponds. Cladocerans were numerically the most important food item ingested in open ponds whereas copepods were numerically the most important food item in stomachs examined from closed ponds. Leptodora were consumed in small quantities in open ponds but were absent in stomachs examined from closed ponds. Tendipedidae pupae were found in stomachs from closed ponds but not from open ponds.

Table 13. Mean number of food organisms per stomach of larval sunfish and percentage of total stomach contents, May 12-July 23, 1978

| | Open ponds | | Closed ponds | | Total | |
|---|---|---|---|---|---|---|
| Number of stomachs | n = 160 (74)[a] | | n = 108 (21) | | n = 268 (95) | |
| Mean total length | TL = 8.1 | | TL = 9.0 | | TL = 8.4 | |
| Organism | No. | % | No. | % | No. | % |
| Rotifera | 0.5 | 14.8 | 0.6 | 3.4 | 0.5 | 6.1 |
| *Leptodora* | t[b] | 0.7 | | | t | 0.2 |
| *Daphnia* | t | 0.2 | t | 0.2 | t | 0.2 |
| *Ceriodaphnia* | t | 0.2 | 0.1 | 0.7 | 0.1 | 0.6 |
| *Bosmina* | 0.2 | 6.1 | 0.1 | 0.8 | 0.2 | 2.1 |
| *Pleuroxus* | t | 1.5 | 0.1 | 0.4 | 0.1 | 0.7 |
| *Chydorus* | 0.4 | 11.8 | 0.1 | 0.8 | 0.3 | 3.4 |
| Unidentified Cladocera | 0.9 | 25.0 | 2.2 | 13.1 | 1.4 | 16.0 |
| Total Cladocera | 1.6 | 45.4 | 2.7 | 16.0 | 2.1 | 23.1 |
| Ostracoda | t | 0.2 | t | 0.1 | t | 0.1 |
| Calanoid copepods | t | 0.3 | 0.1 | 0.4 | t | 0.4 |
| Cyclopoid copepod | 1.0 | 28.9 | 9.5 | 56.5 | 4.5 | 49.8 |
| Copepod nauplii | 0.2 | 5.9 | 3.3 | 19.5 | 1.5 | 16.2 |
| Total Copepoda | 1.3 | 35.1 | 12.9 | 76.4 | 5.9 | 66.4 |
| Tendipedidae larvae | 0.1 | 3.3 | 0.5 | 3.0 | 0.3 | 3.1 |
| Tendipedidae pupa | | | t | t | t | t |
| Insect | t | 1.2 | 0.2 | 1.1 | 0.1 | 1.1 |
| Total | 3.6 | | 16.8 | | 8.9 | |

[a] Number of empty stomachs in parentheses.

[b] t = less than 0.1.

Crappie

Stomachs of 184 crappie collected from the study ponds during May and June were examined. Fish ranged in size from 4 to 13 mm TL. Seventeen stomachs contained no food items, and four fish still had yolk sac material present. Most empty stomachs were from fish less than 7 mm TL. Cladocerans and copepods were the major groups of food organisms ingested and made up 97% of the total number of food items found in stomachs (Table 14).

Crappie from closed ponds had on the average 1.3 times as many food items per stomach as crappie from open ponds. Cyclopoid copepods were the most abundant organisms found in crappie stomachs from open ponds, whereas copepod nauplii were the most abundant food item in stomachs from closed ponds. Unidentified cladocerans or cladocerans too mutilated to identify were the principal cladocerans consumed. Daphnia, Bosmina, and Pleuroxus were ingested in small quantities in both open and closed ponds. Leptodora, Chydorus, and Ostracoda were found only in stomachs from open ponds and Ceriodaphnia was found only in stomachs from closed ponds.

Many of the organisms consumed (Chydorus, Alona, Pleuroxus, and Ceriodaphnia) are typically littoral inhabitants and not generally considered to be components of the limnetic plankton (Edmondson 1959). Hence, electivity values (Ivlev 1961) could not be computed for larval carp, sunfish, or crappie because the fishes were utilizing a food resource which was not represented in the limnetic plankton samples used to determine food availability.

Table 14. Mean number of food organisms per stomach of larval crappie and percentage of total stomach contents, May 12-July 23, 1978

| | Open ponds | | Closed ponds | | Total | |
|---|---|---|---|---|---|---|
| Number of stomachs | n = 77 (11)[a] | | n = 107 (6) | | n = 184 (17) | |
| Mean total length | TL = 7.8 | | TL = 6.7 | | TL = 7.2 | |
| Organism | No. | % | No. | % | No. | % |
| Rotifera | 0.2 | 1.8 | 0.4 | 3.6 | 0.4 | 2.9 |
| _Leptodora_ | 0.2 | 1.6 | | | 0.1 | 0.6 |
| _Daphnia_ | t[b] | 0.3 | t | 0.2 | t | 0.2 |
| _Ceriodaphnia_ | | | t | 0.2 | t | 0.2 |
| _Bosmina_ | 0.1 | 1.1 | t | 0.1 | t | 0.4 |
| _Pleuroxus_ | t | 0.4 | t | 0.1 | t | 0.2 |
| _Chydorus_ | t | 0.4 | | | t | 0.1 |
| Unidentified Cladocera | 2.6 | 22.9 | 0.5 | 4.2 | 1.3 | 10.7 |
| Total Cladocera | 3.1 | 26.7 | 0.6 | 4.8 | 1.5 | 12.4 |
| Ostracoda | | | t | 0.1 | t | t |
| Calanoid copepods | 0.1 | 1.1 | 0.3 | 2.5 | 0.2 | 1.9 |
| Cyclopoid copepods | 5.7 | 57.8 | 5.3 | 42.3 | 5.5 | 46.9 |
| Copepod nauplii | 1.2 | 12.2 | 6.3 | 50.3 | 4.2 | 35.8 |
| Unidentified copepods | t | 0.3 | | | t | 0.1 |
| Total Copepoda | 7.0 | 71.4 | 11.9 | 95.1 | 9.9 | 84.6 |
| Total | 9.9 | | 12.6 | | 11.7 | |

[a] Number of empty stomachs in parentheses.

[b] t = less than 0.1.

## Growth of Young-of-the-Year Fish

A variety of ecological factors including temperature, food supply, and competition affects growth of fish. Hence, differences in the growth rate among different bodies of water can reflect differences in the environment where the fish are living.

The growth of the eight most abundant species in the study ponds was estimated by regression formulae calculated from mean total lengths for the period May 12-August 4 (Table 15). Considerable variation in length within each species on each sample date was evident (Figures D.1-D.8). Analysis of covariance indicated that growth rates of all but two groups (gizzard shad and sauger-walleye) were not significantly different between the ponds ($P > 0.05$). Calculated growth rate ($\beta$) for gizzard shad was lowest in Pond 1 (0.8 mm/day) and highest in Pond 4 1.6 mm/day). The slope of the regression line was not common for the four ponds ($F = 2.99$, $P > 0.05$) and the fit of the regression line for gizzard shad in Pond 1 was especially poor ($r = 0.645$). Calculated growth in Pond 1 was low because small fish dominated the July samples and few large juveniles were captured.

Sauger-walleye was the only other taxa which showed significant differences in growth between ponds ($F = 7.65$, $P < 0.05$). Growth was fastest in Pond 3 (2.2 mm/day) and slowest in Pond 1 (0.9 mm/day). Closer inspection of the data revealed that the high calculated rate of growth in Pond 3 was the result of a single 127 mm fish captured in late July. Growth rate was similar in all ponds when this fish was excluded from the calculations.

Table 15. Regressions[a] of growth for young-of-the-year fishes from the study ponds based on date collected from May 12 - August 4 and calculated and observed lengths on on July 15, 1978

| Species | Pond | Number of observations | α | β | Mean length on July 15 | |
|---|---|---|---|---|---|---|
| | | | | | Calculated[b] | Observed |
| Gizzard shad | 1 | 9 | -14.9 | 0.8 | | 82 |
| | 2 | 15 | -30.2 | 1.1 | | 37 |
| | 3 | 11 | -38.1 | 1.2 | 53 | 46 |
| | 4 | 9 | -48.8 | 1.6 | 73 | |
| Pooled | | 44 | -32.9 | 1.1 | 51 | 55[c] |
| Carp | 1 | 9 | -42.7 | 1.3 | 56 | 56 |
| | 2 | 10 | -49.2 | 1.4 | 57 | 87 |
| | 3 | 12 | -45.0 | 1.2 | 46 | 9 |
| | 4 | 12 | -61.9 | 1.8 | 75 | |
| | 5 | 11 | -37.8 | 1.5 | 76 | 100 |
| Pooled | | 54 | -50.6 | 1.5 | 63 | 61[c] |
| Suckers | 1 | 13 | -26.8 | 1.0 | 49 | |
| | 2 | 13 | -16.9 | 0.9 | 52 | 63 |
| | 3 | 13 | -14.1 | 0.6 | 32 | 7 |
| | 4 | 8 | -47.5 | 1.5 | 67 | |
| | 5 | 5 | -72.5 | 1.8 | 64 | 59 |
| Pooled | | 52 | -29.2 | 1.0 | 47 | 43[c] |
| Sunfish | 1 | 7 | -20.5 | 0.5 | 17 | 14 |
| | 2 | 11 | -30.0 | 0.7 | 23 | 14 |
| | 3 | 8 | -20.0 | 0.5 | 18 | 10 |
| | 4 | 6 | -18.6 | 0.5 | 19 | 10 |
| | 5 | 8 | -20.0 | 0.6 | 26 | 23 |
| Pooled | | 44 | -25.4 | 0.6 | 20 | 14[c] |
| Largemouth bass | 1 | 7 | -30.2 | 0.9 | 38 | 33 |
| | 2 | 6 | -26.4 | 1.0 | 50 | |
| | 3 | 5 | -61.3 | 1.4 | 45 | 46 |
| | 4 | 4 | -50.4 | 1.3 | 48 | 53 |
| Pooled | | 22 | -39.9 | 1.1 | 46 | 44[c] |
| Crappie | 1 | 13 | -25.6 | 0.9 | 43 | 40 |
| | 2 | 14 | -18.3 | 0.8 | 43 | 41 |
| | 3 | 9 | -21.4 | 0.9 | 47 | 47 |
| | 4 | 13 | -19.1 | 0.8 | 42 | 49 |
| | 5 | 12 | -33.2 | 1.0 | 43 | 38 |
| Pooled | | 61 | -23.4 | 0.8 | 43 | 43[c] |
| Yellow perch | 1 | 5 | -18.4 | 0.8 | 42 | |
| | 2 | 3 | -15.1 | 0.8 | 46 | 43 |
| | 3 | 5 | -10.2 | 0.6 | 35 | |
| | 5 | 6 | -14.0 | 1.3 | 81 | 73 |
| Pooled | | 19 | -14.3 | 1.0 | 62 | 58[c] |
| Sauger-walleye | 1 | 8 | -14.1 | 0.9 | 54 | |
| | 2 | 9 | -33.0 | 1.6 | 89 | 89 |
| | 3 | 8 | -79.4 | 2.2 | 88 | |
| Pooled | | 25 | -39.4 | 1.6 | 82 | 89[c] |

[a] $Y = \alpha + \beta x$, where $\beta$ = growth in millimeters per day, y = length, x = days after May 1.

[b] $Y = \alpha + \beta x$, where x = July 15 (or 76 days after May 1).

[c] Mean of the observed means on July 15.

All taxa except sunfish showed slightly higher mean growth rates in closed ponds (Table 16). In open ponds, sauger-walleye were the fastest growers (1.56 mm/day) and sunfish grew the slowest (0.58 mm/day) during the period May 12-August 4. Carp and suckers were the fastest growers, and sunfish again the slowest in closed ponds.

Growth rates of fish in the study ponds were also compared with growth of fish from other waters of a similar latitude to assess the suitability of Missouri River backwaters for the species studied (Table 17). Calculated total lengths for fish captured in the study ponds on July 15 were compared with fish from Clear Lake, Iowa, and Gavins Point Reservoir, South Dakota. Mean lengths in the backwater ponds were similar to those from the other lakes with the exception of crappie which showed better growth in the Missouri River ponds than black crappie in Clear Lake. However, the mean length on July 15 of crappie (primarily white crappie) from the backwater ponds was the same as the mean length of white crappie in July (43 mm) as quoted by Carlander (1977).

## Spawning Period

Considerable variation was noted in the species utilizing the various study ponds for reproduction and in the timing and length of the spawning period and time of hatching. Time of hatching was estimated from first observations of larvae and also by projecting backwards linear growth regressions of y.o.y. fishes (Table 18). This projection based on body length had the effect of reducing the hatching period to a single point in time and averaged the time of hatch of all broods. Length of the hatching period was estimated by noting how long larvae less than 10 mm TL

Table 16. Calculated mean growth rate (mm/day) of eight species in open and closed ponds

| Species | Open ponds | Closed ponds |
|---|---|---|
| Gizzard shad | 1.00 | 1.57 |
| Carp | 1.20 | 1.65 |
| Suckers | 0.82 | 1.66 |
| Sunfish | 0.58 | 0.54 |
| Crappie | 0.84 | 0.90 |
| Largemouth bass | 1.09 | 1.34 |
| Yellow perch | 0.72 | 1.25 |
| Sauger-walleye | 1.56 | |

Table 17. Comparison of mean total length (mm) of young-of-the-year fishes on July 15 of selected species from Missouri River backwater ponds, Clear Lake, Iowa, and Gavins Point Reservoir

| Taxonomic group | Study ponds | | Other Waters | | |
|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Source |
| Gizzard shad | 51 | 46-73 | 56 | 30-123 | Sprague (1961) Gavins Point Reservoir |
| Carp | 63 | 46-76 | 66 | 25-94 | Bailey (1943) Clear Lake |
| Suckers | 47 | 32-64 | 46 | 25-64 | Bailey (1943) Clear Lake |
| Sunfish | 20 | 17-26 | 19 | 7-22 | Ridenhour (1958) Clear Lake |
| Crappie | 43 | 42-47 | 26 | 14-37 | Ridenhour (1958) Clear Lake |
| Largemouth bass | 46 | 38-50 | 38 | 22-57 | Ridenhour (1958) Clear Lake |
| Yellow perch | 62 | 42-81 | 52 | 45-61 | Ridenhour (1958) Clear Lake |
| Sauger-walleye | 82 | 54-89 | 71 | 59-107 | Ridenhour (1958) Clear Lake |

Table 18. Date of first appearance of larval fishes in Miller and tow net catches and calculated date of hatching[a]

| Taxonomic group | Open ponds | | | | | | Closed ponds | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | |
| | Obs. | Calc. | Obs. | Calc. | Obs. | Calc. | Obs. | Calc. | Obs. | Calc. |
| Paddlefish | 6/9 | | | | | | | | | |
| Shortnose gar | 6/9 | | | | | | 6/18 | | | |
| Gizzard shad | 6/2 | 5/26 | 5/27 | 6/3 | 6/3 | 6/6 | 6/2 | 6/3 | 7/12[b] | |
| Goldeye | 6/18[c] | | | | 7/27[c] | | | | | |
| Carp | 6/2 | 6/6 | 5/27 | 6/8 | 6/3 | 6/2 | 5/26 | 6/6 | 6/4 | 5/28 |
| Fathead minnow | | | | | | | 5/26 | | 6/4 | |
| Other minnow | 5/12 | | 5/13 | | 5/13 | | | | | |
| Suckers | 5/19 | 6/1 | 5/20 | 5/24 | 5/20 | 6/1 | 6/2 | 6/4 | 6/20 | 6/12 |
| Black bullhead | 7/7 | | 7/13[c] | | | | 6/26 | | 6/24 | |
| Channel catfish | | | 7/7 | | 7/6[c] | | 7/8[bc] | | | |
| Tadpole madtom | | | | | | | 7/7 | | 6/24 | |
| Flathead catfish | | | 7/7[c] | | | | | | | |
| White bass | 7/7[c] | | 6/23[c] | | 7/13 | | 7/6[b] | | 7/26[a] | |
| Sunfish | 6/14 | 6/20 | 6/7 | 6/19 | 6/7 | 6/19 | 6/18 | 6/16 | 6/4 | 6/11 |
| Largemouth bass | 6/14 | 6/8 | 6/15 | 5/31 | 6/20 | 6/16 | 6/22 | 6/12 | 7/12[ab] | |
| Crappie | 5/26 | 6/3 | 5/27 | 5/29 | 5/27 | 5/29 | 5/26 | 5/30 | 6/4 | 6/7 |
| Darter | 6/9 | | 6/3 | | 6/3 | | | | | |
| Yellow perch | 6/2 | 5/29 | 6/3 | 5/25 | 6/3 | 6/2 | | | 6/4 | 5/15 |
| Sauger-walleye | 5/19 | 5/21 | 5/20 | 5/24 | 6/3 | 6/7 | | | | |
| Freshwater drum | 6/18 | | 6/12 | | 6/20 | | 7/7[b] | | | |

[a] Fish were assumed to be 5 mm long at hatching. The growth regression formulae (length = $\alpha + \beta$ (days after May 1)) from Table 13 was used to calculate the date of hatch; e.g., gizzard shad in Pond 5 = $-14.9 + 0.8x$, where x = 26 days from May 1 = May 26.

[b] Captured after the pond was connected with the main channel.

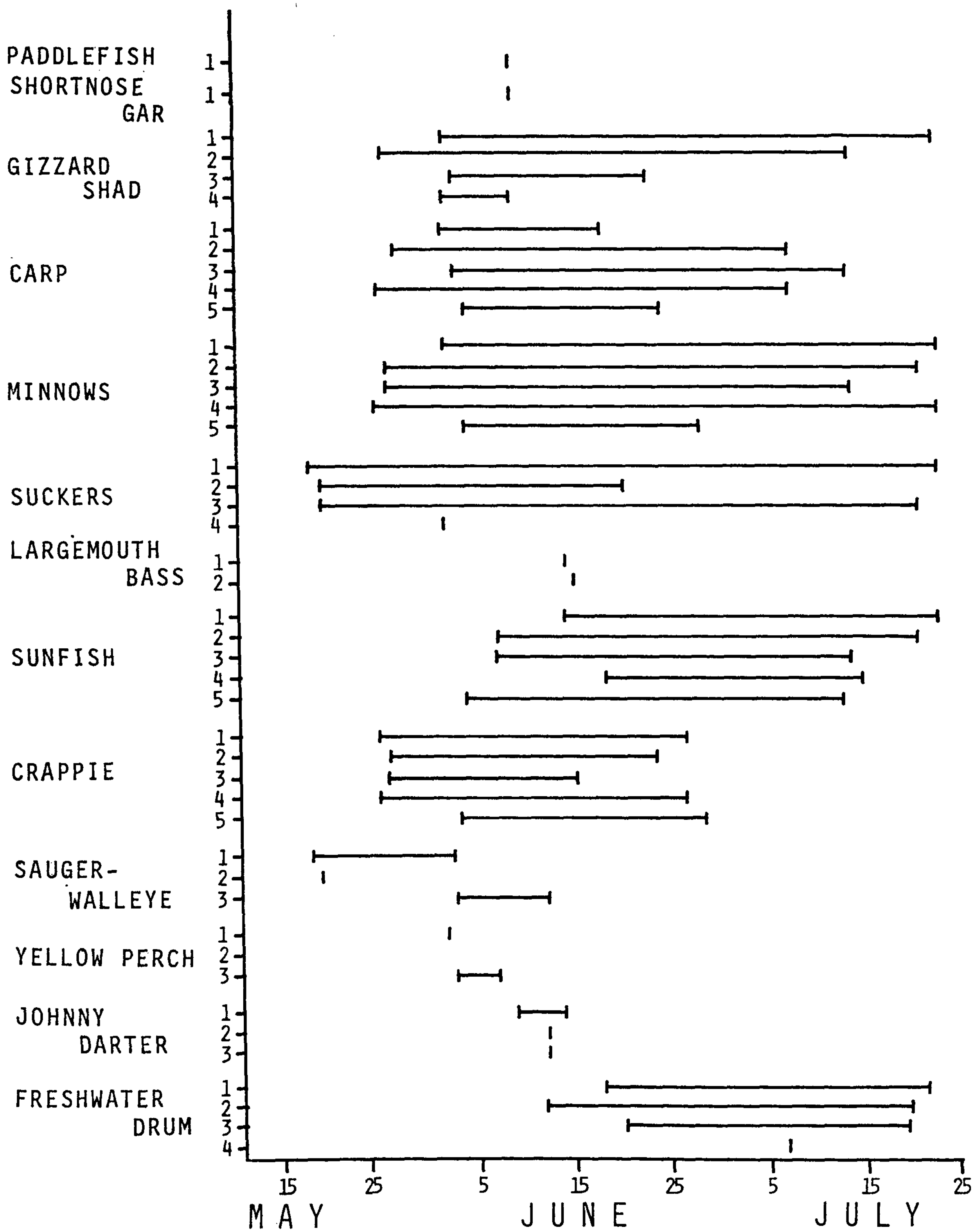
[c] Captured with seine or trap net.

appeared in the catch. Suckers, minnows, and sauger-walleye were the first taxa to appear in the samples and evidently had begun hatching by mid May in most ponds, although sauger-walleye were not captured in Pond 3 until early June. Gizzard shad, carp, crappie, and yellow perch had commenced hatching by June 1 in most ponds. Shortnose gar, largemouth bass, sunfish, and darters had started hatching by mid June, and freshwater drum was the last species to begin hatching in June. Hatching dates for some species such as white bass were difficult to estimate because of insufficient growth data and the absence of fish smaller than 10 mm TL in the samples.

Differences between observed dates of first capture and calculated dates of hatching were attributed to two factors: 1) fish were frequently larger than hatching size (5 mm) when they were first captured; and 2) the calculated regression line averaged the hatching dates of several broods so that calculated dates were often later than dates when actual hatching commenced. The method did provide another estimate of the spawning and hatching period.

Some species spawned over an extended period; others completed spawning in a few days. Short term spawners included sauger-walleye, yellow perch, johnny darter, and largemouth bass (Figure 5). Gizzard shad, carp, minnows, suckers, sunfish, crappie, and freshwater drum appeared to spawn over an extended period. Larvae less than 10 mm TL of gizzard shad, carp, suckers, minnows, sunfish, crappie, and freshwater drum were caught during a period lasting more than 30 days. Samples of paddlefish and gar were insufficient to determine length of the spawning period. Length of the spawning period was unrelated to whether ponds were open or closed to the river although gizzard shad spawned for a shorter period of time in closed Pond 4 than in other ponds.

Figure 5. Period of time when fishes less than 10 mm TL were captured in the study ponds. Numbers on vertical axis refer to pond numbers


PADDLEFISH
SHORTNOSE GAR
GIZZARD SHAD
CARP
MINNOWS
SUCKERS
LARGEMOUTH BASS
SUNFISH
CRAPPIE
SAUGER-WALLEYE
YELLOW PERCH
JOHNNY DARTER
FRESHWATER DRUM
15 25 5 15 25 5 15 25
MAY
JUNE
JULY

# DISCUSSION

Backwater ponds of the channelized Missouri River are important areas for fish reproduction because of the lack of quiet water in the channelized river. The still water, partially submerged emergent vegetation, and rock rip-rap in the ponds provide suitable spawning habitat for many fish species native to the river. Based on catches of running-ripe adults and large catch per effort of small larvae (0-10 mm TL), at least 15 species spawned in the study ponds. Another 10 species used the study ponds as nursery areas and may have spawned in them. Catches of larvae in tow nets were generally more than 10 times greater in ponds than reported in the main channel drift from other studies.

Surface water connections between backwater ponds and the main channel of the river are essential for the repopulation of the ponds after periodic winterkills. Notching dikes which separate the ponds from the main channel of the river can effectively connect backwater ponds with the river. Connection can also occur when discharges from Gavins Point Reservoir are sufficient to raise the water level over the top of dikes separating the ponds from the main channel.

More species of adult fish were captured in open ponds than in closed ponds. Twenty-six species of adult fish were captured during May and June, 1978 in open ponds. In closed ponds, on the other hand, only twelve species of adult fish were captured. Fish movement between open ponds and the main channel was evidently common.

Suitable substrates and conditions for spawning were present in all ponds for most species of fish encountered in the river. Therefore, the use of a study pond as a spawning and/or nursery area by a particular species was apparently dependent upon the ability of adults and juveniles of that species to enter the pond. Adult entry was possible into closed ponds only after the spawning season during 1978. The freshwater drum was an exception and was able to spawn in Pond 4 during July. During years of normal flow (575 $m^3$/sec), fish are not able to enter closed ponds, hence only those species which are able to survive severe winter conditions are present to spawn. For example, the abundance of black bullheads and fathead minnows in closed ponds suggests that the ponds have suffered winterkills in the past. Both species are often found in lakes which winterkill on a regular basis.

More species of young-of-the-year fish were also captured in open ponds than in closed ponds. Young-of-the-year blue sucker, smallmouth buffalo, shorthead redhorse, darter, sauger-walleye, and flathead catfish were caught exclusively in open ponds. Single specimens of young-of-the-year channel catfish and white bass were captured in closed ponds only after the ponds were connected with the river by high water levels.

The study ponds provided suitable habitat for the development and growth of many species of y.o.y. fishes. Growth of y.o.y. fish in the study ponds was comparable to growth in Clear Lake, Iowa, and in Lewis and Clark Lake, South Dakota. Young-of-the-year fish in closed ponds showed slightly greater growth than fish in open ponds.

The study ponds are also important sites for zooplankton production because there are relatively few productive areas available in the channelized river (Berner 1951, Morris et al. 1968). Zooplankton densities in the study ponds were more than 25 times greater than in the main channel drift. Although Van Dorn Bottle samples were surprisingly similar among open and closed ponds, Miller and tow net samples indicated a greater abundance of zooplankton in closed ponds than in open ponds.

Stomachs of y.o.y. carp, bluegill, and crappie from closed ponds contained greater numbers of zooplankton than did stomachs of fish examined from open ponds. Greater growth of y.o.y. fish in closed ponds can be explained by greater zooplankton densities and greater numbers of food items in the stomachs of fish from closed ponds.

Notching dikes allows fish to move into backwater ponds but also allows river-carried sediments to enter the ponds. Sediment deposition was apparent in open ponds. Higher turbidity levels in the open ponds may have caused lower zooplankton production, less efficient feeding by y.o.y. fish, and consequently slower growth of y.o.y. fish in open ponds than in closed ponds.

Sediment deposition coupled with bed scour and main channel degradation are acting to shorten the life of the ponds. Connecting backwater ponds with the main channel is beneficial to the fishery of the Missouri River because it provides fish with access to essential spawning areas, but notching is only a short-term relief measure. Sediment deposition will eventually isolate the ponds from the main channel, or fill in the ponds with sediment. An experiment conducted at the U.S. Army Corps of Engineers movable bed river model at Fort Mead, Nebraska, demonstrated that quiet waters behind revetment structures fill with sediment in a relatively short time. Unless the present management plan for the river is altered, bed scour and sedimentation will destroy the few remaining backwater areas which are crucial for fish reproduction.

Attempts to reduce sedimentation yet retain a connection between backwater ponds and the main channel have included placement of the connecting notch at the extreme downstream end of the backwater pond. An oxbow lake on the Iowa River near Hill, Iowa (Iowa Natural Resources Council Order No. 69-161) was constructed with this design and has remained open to the river for several years (R. V. Bulkley, Iowa State University, Ames, Iowa, personal communication, 1979). Notch designs which include deflection baffles such as the one recommended for the Sioux City boat marina entrance may also be effective in controlling sediment deposition in backwaters (U.S. Army Corps of Engineers 1967). This design creates a turbulence at the notch opening that discourages sediment deposition.

Sayre and Kennedy (1978) identified several possible measures to reduce the present rate of degradation on the Missouri River. One important recommendation is the partial removal of bank protection structures so that the channel is widened and the current velocity reduced. The sediment transport capacity of the river is thereby diminished. The possibility of reverting to a 180 m wide navigation channel compared to the present 90 m wide main channel between revetments has been suggested (M. D. Dougal, Iowa State University, Ames, Iowa, personal communication, 1979). This would benefit fish and wildlife but might result in an inadequate navigation channel. However, the number of tows plying the river between Sioux City and Omaha is small. The tonnage hauled between Omaha and Sioux City represents approximately 10% of the tonnage moved on the Upper Mississippi River (Iowa Natural Resources Council 1978).

The development of existing oxbows or creation of new oxbows or side channels by pumping, dredging, or other means to maintain sufficient depth has been suggested by several Iowa workers (Lohnes et al. 1977, Sayre and Kennedy 1978, Wolff 1978).

These suggestions hold more long-term promise for increasing quiet water habitat on the Missouri River than does the present notching program. Continued interest and research into these alternatives is recommended.

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APPENDIX A. SPECIES OF FISH COLLECTED FROM THE STUDY PONDS, MAY 12-AUGUST 4, 1978[a]

| | |
|---|---|
| Paddlefish | *Polyodon spathula* |
| Shortnose gar | *Lepisosteus platostomus* |
| American eel | *Anguilla rostrata* |
| Gizzard shad | *Dorosoma cepedianum* |
| Goldeye | *Hiodon alosoides* |
| Carp | *Cyprinus carpio* |
| Emerald shiner | *Notropis atherinoides* |
| Bigmouth shiner | *Notropis dorsalis* |
| Red shiner | *Notropis lutrensis* |
| Sand shiner | *Notropis stramineus* |
| Fathead minnow | *Pimephales promelas* |
| Creek chub | *Semotilus atromaculatus* |
| River carpsucker | *Carpiodes carpio* |
| Quillback carpsucker | *Carpiodes cyprinus* |
| White sucker | *Catostomus commersoni* |
| Blue sucker | *Cycleptus elongatus* |
| Smallmouth buffalo | *Ictiobus bubalus* |
| Bigmouth buffalo | *Ictiobus cyprinellus* |
| Shorthead redhorse | *Moxostoma macrolepidotum* |
| Blue catfish | *Ictalurus furcatus* |
| Black bullhead | *Ictalurus melas* |
| Channel catfish | *Ictalurus punctatus* |
| Stonecat | *Noturus flavus* |
| Tadpole madtom | *Noturus gyrinus* |
| Flathead catfish | *Pylodictus olivaris* |
| White bass | *Morone chrysops* |
| Green sunfish | *Lepomis cyanellus* |
| Orangespotted sunfish | *Lepomis humilis* |
| Bluegill | *Lepomis macrochirus* |
| Largemouth bass | *Micropterus salmoides* |
| White crappie | *Pomoxis annularis* |
| Black crappie | *Pomoxis nigromaculatus* |
| Johnny darter | *Etheostoma nigrum* |
| Yellow perch | *Perca flavescens* |
| Sauger | *Stizostedion canadense* |
| Walleye | *Stizostedion vitreum* |
| Freshwater drum | *Aplodinotus grunniens* |

[a] Nomenclature according to Bailey et al. (1970).

# APPENDIX B. SEASONAL CATCH PER EFFORT OF FISHES WITH TOW NET AND SEINE IN THE STUDY PONDS, MAY 12-AUGUST 4, 1978

Figure B.1. Seasonal catch per effort of gizzard shad with tow net and seine in the study ponds, May 12-August 4, 1978

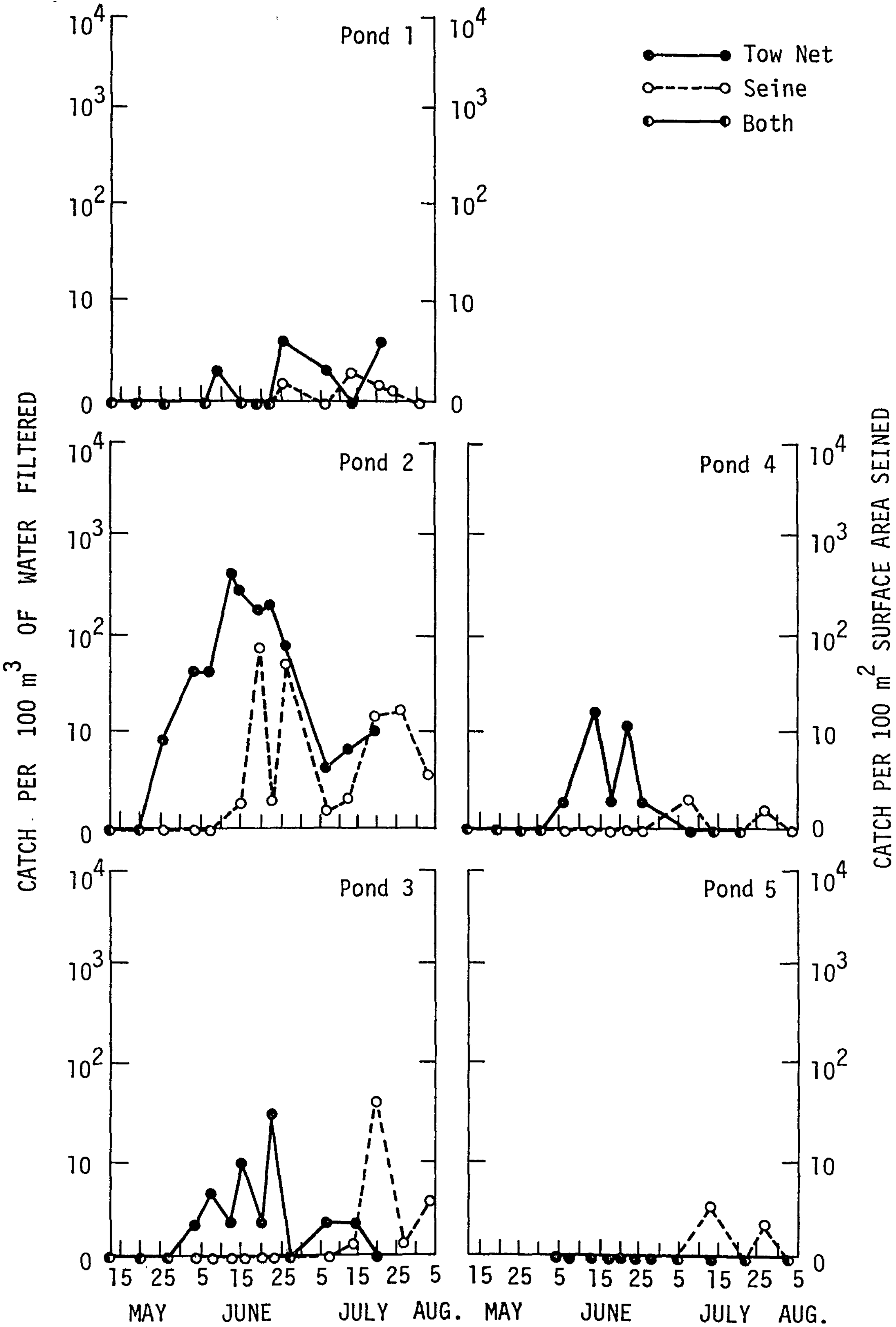

Tow Net
Seine
Both
Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
CATCH PER 100 m3 OF WATER FILTERED
CATCH PER 100 m2 SURFACE AREA SEINED
0
10
10^2
10^3
10^4
15 25 5 15 25 5 15 25 5
MAY JUNE JULY AUG.

Figure B.2. Seasonal catch per effort of carp with tow net and seine in the study ponds, May 12-August 4, 1978

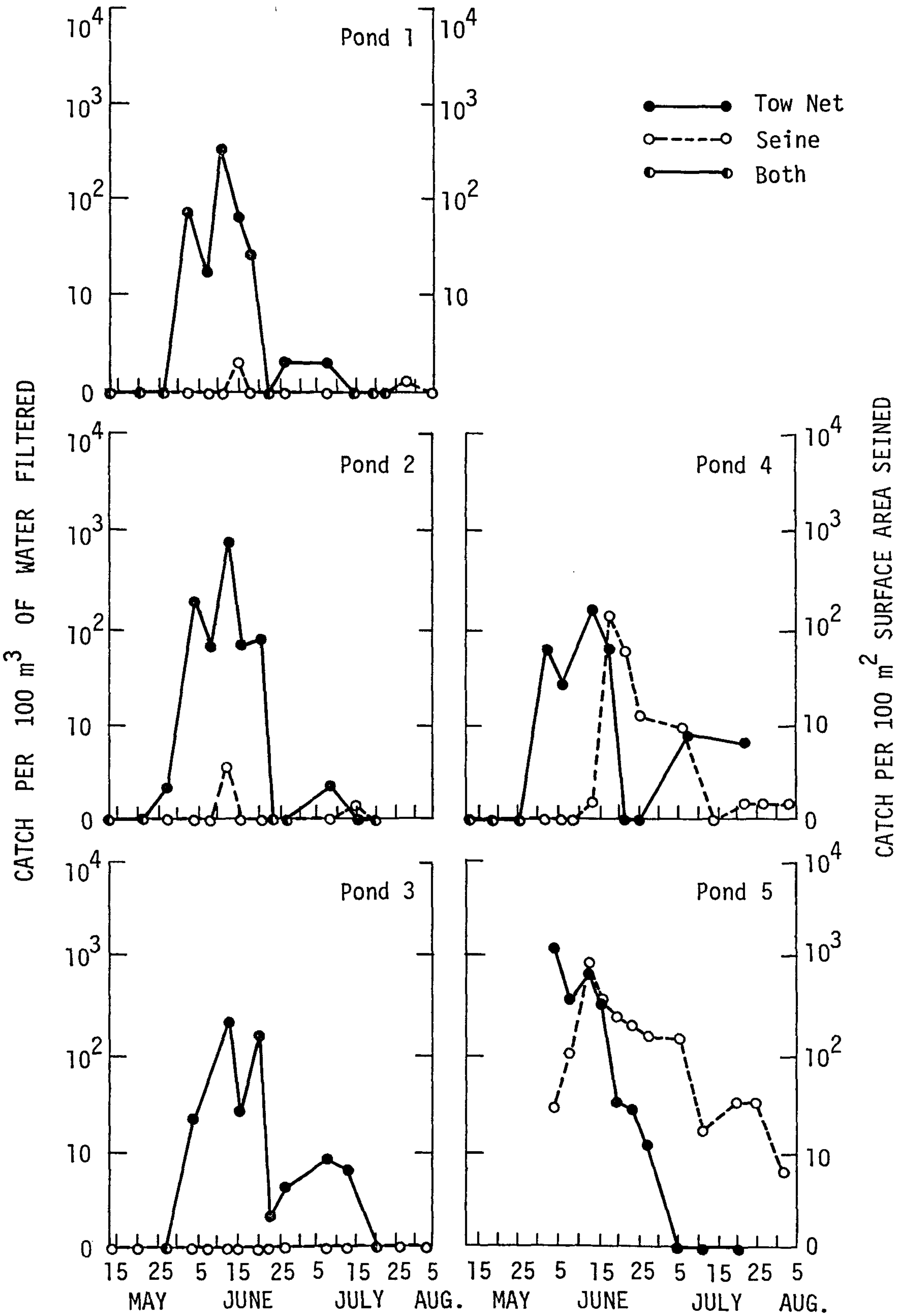
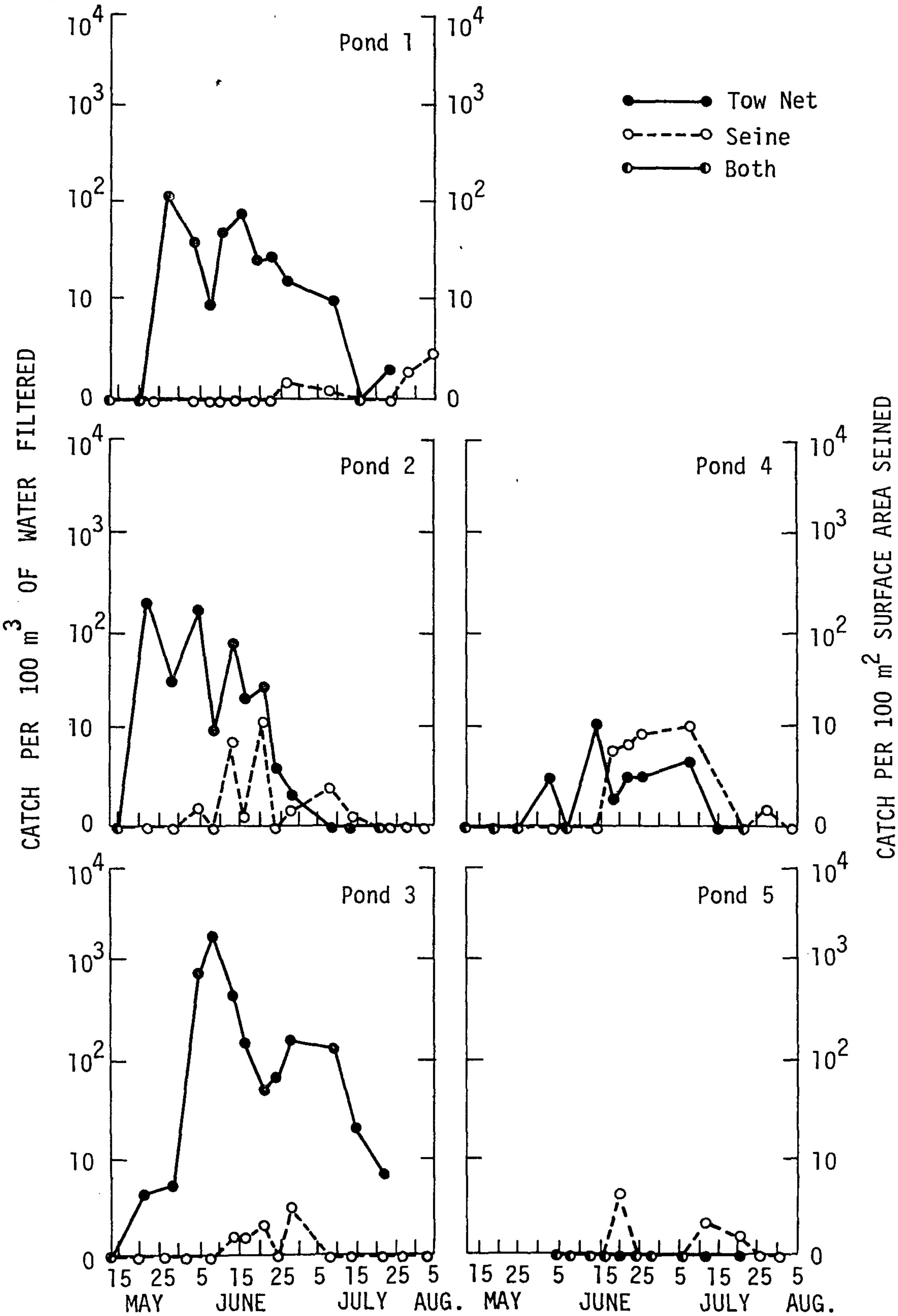

Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
Tow Net
Seine
Both
CATCH PER 100 m3 OF WATER FILTERED
CATCH PER 100 m2 SURFACE AREA SEINED
0
10
10^2
10^3
10^4
15 25 5 15 25 5 15 25 5
MAY JUNE JULY AUG.

Figure B.3. Seasonal catch per effort of suckers with tow net and seine in the study ponds, May 12-August 4, 1978



Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
Tow Net
Seine
Both
CATCH PER 100 m3 OF WATER FILTERED
CATCH PER 100 m2 SURFACE AREA SEINED
10⁴
10³
10²
10
0
15 25 5 15 25 5 15 25 5
MAY JUNE JULY AUG.

Figure B.4. Seasonal catch per effort of minnows with tow net in the study ponds, May 12-August 4, 1978

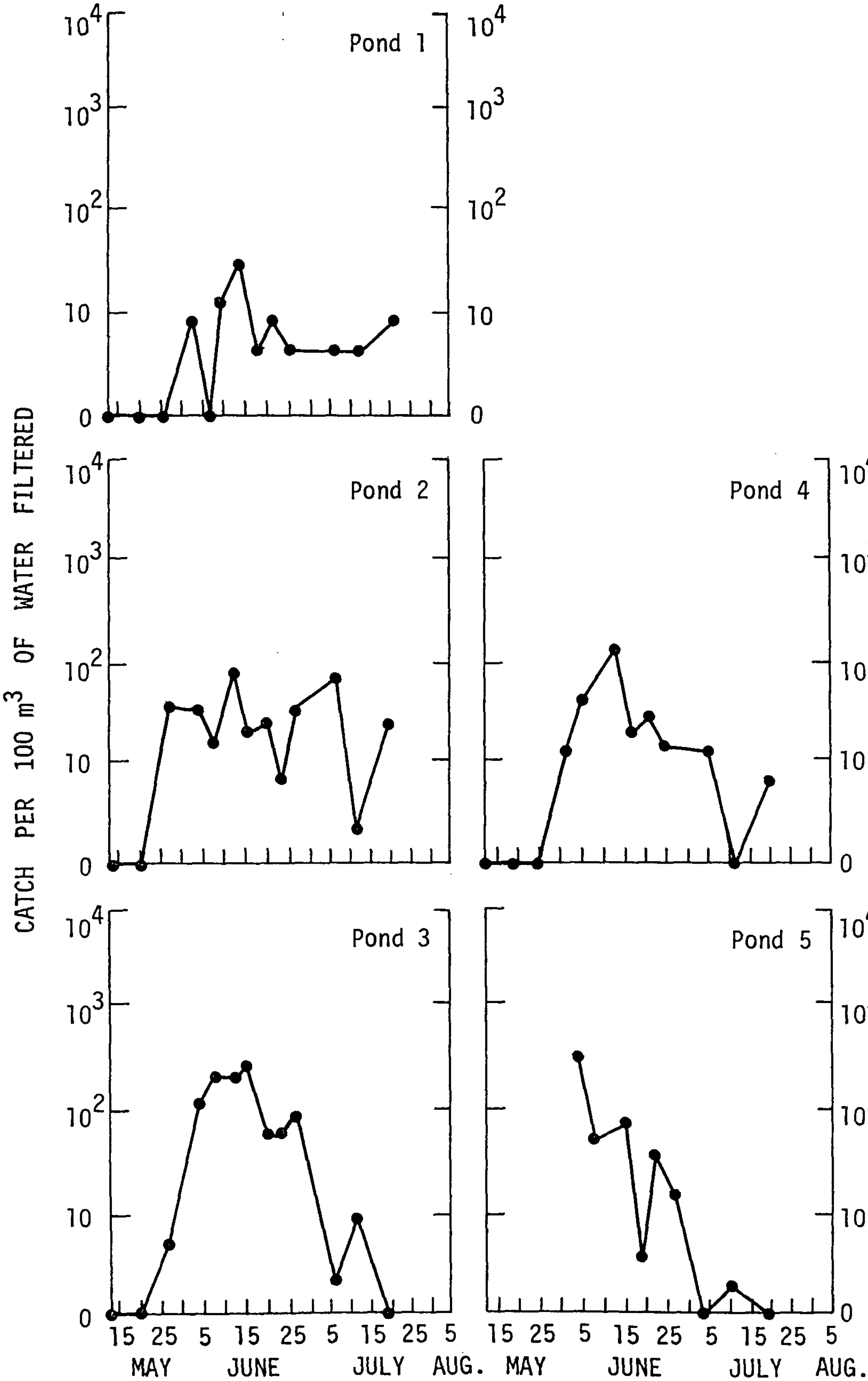

Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
CATCH PER 100 m3 OF WATER FILTERED
$10^4$
$10^3$
$10^2$
10
0
15 25 5 15 25 5 15 25 5
MAY JUNE JULY AUG.

Figure B.5. Seasonal catch per effort of sunfish with tow net and seine in the study ponds, May 12-August 4, 1978

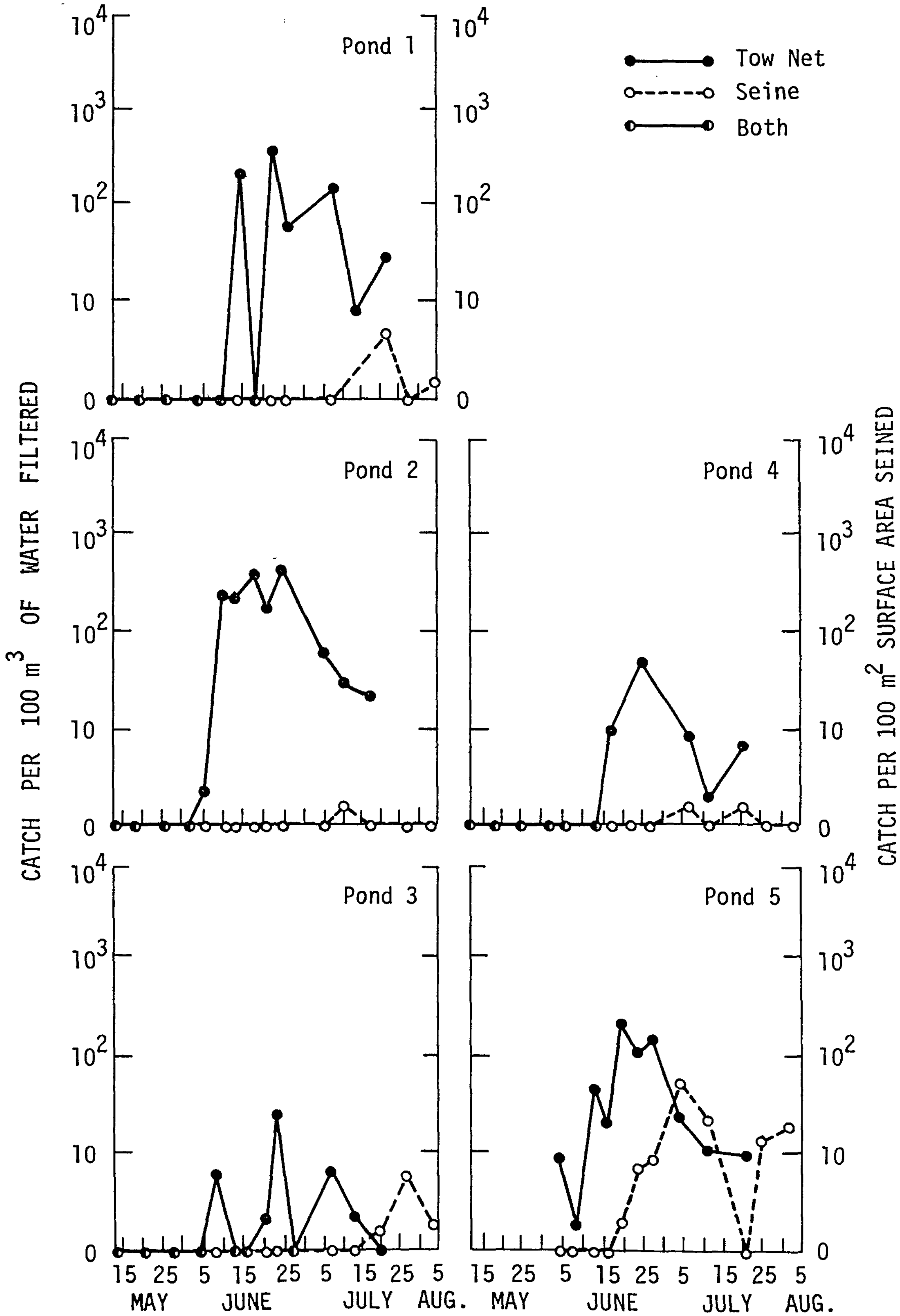

Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
Tow Net
Seine
Both
CATCH PER 100 m3 OF WATER FILTERED
CATCH PER 100 m2 SURFACE AREA SEINED
15 25 5 15 25 5 15 25 5
MAY JUNE JULY AUG.

Figure B.6. Seasonal catch per effort of crappie with tow net and seine in the study ponds, May 12-August 4, 1978

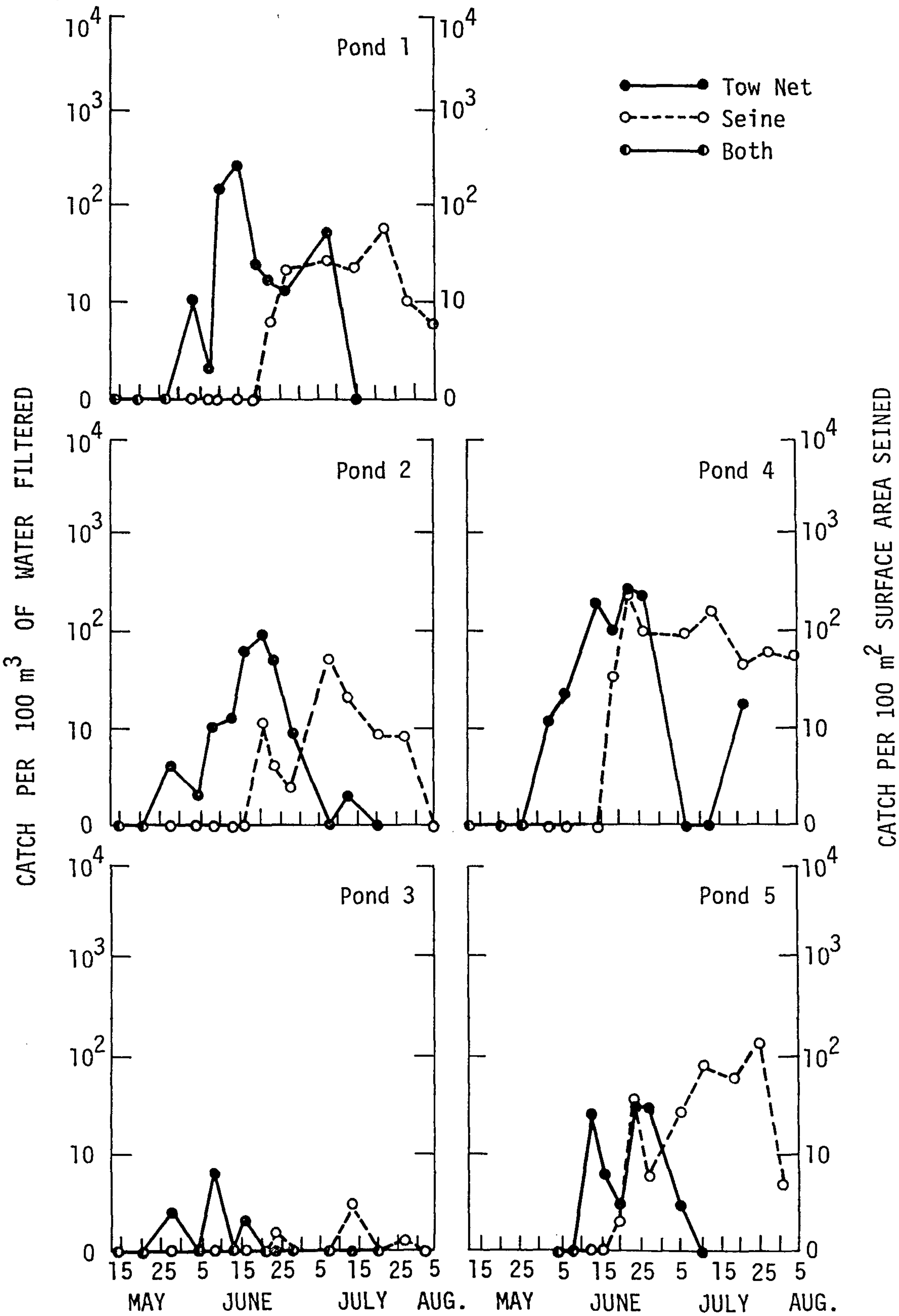

Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
Tow Net
Seine
Both
CATCH PER 100 m3 OF WATER FILTERED
CATCH PER 100 m2 SURFACE AREA SEINED
15 25 5 15 25 5 15 25 5
MAY JUNE JULY AUG.

Figure B.7. Seasonal catch per effort of sauger-walleye with tow net and seine in the study ponds, May 12-August 4, 1978

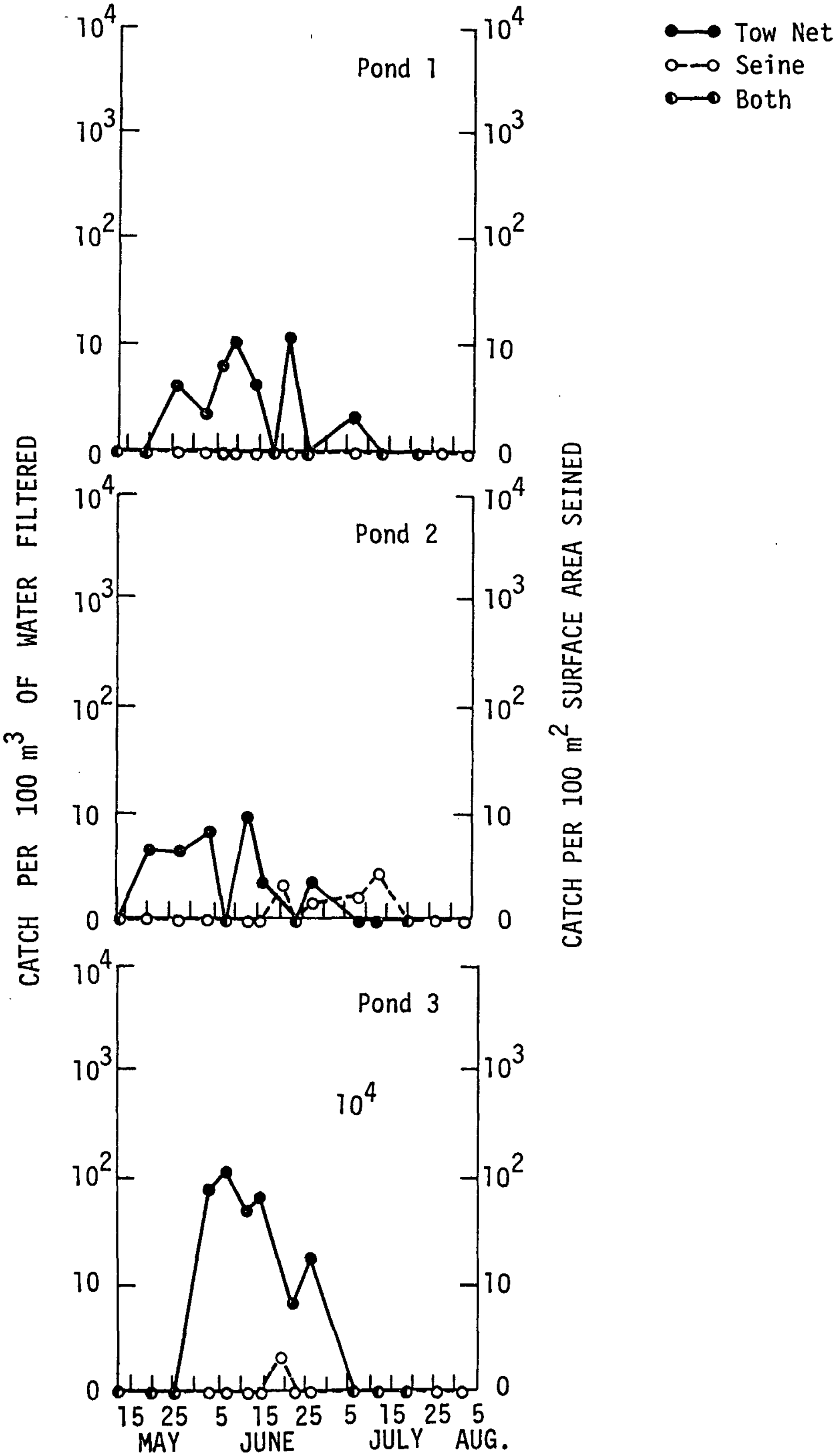
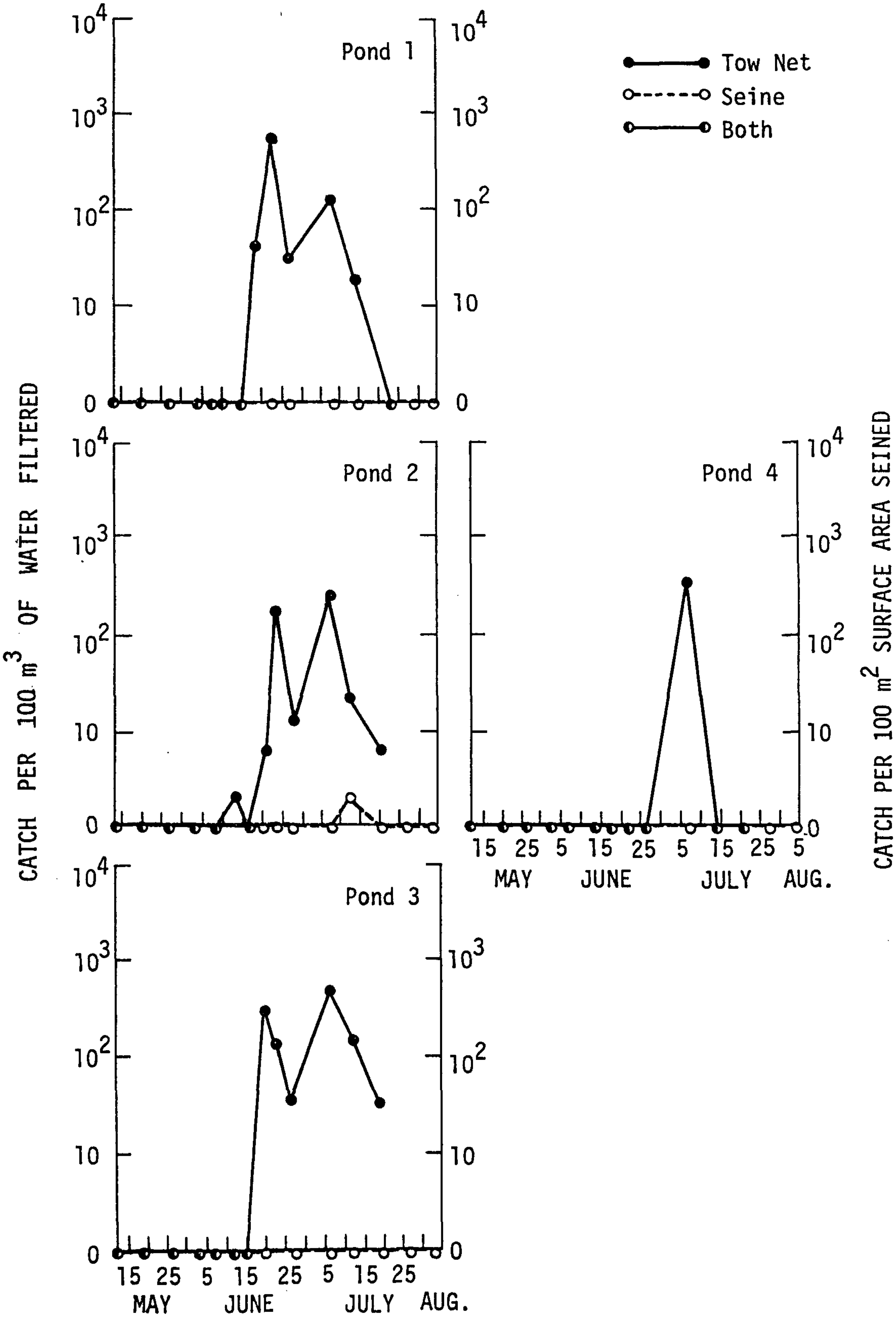

Tow Net
Seine
Both
Pond 1
Pond 2
Pond 3
$10^4$
$10^3$
$10^2$
10
0
CATCH PER 100 $m^3$ OF WATER FILTERED
CATCH PER 100 $m^2$ SURFACE AREA SEINED
15 25 5 15 25 5 15 25 5
MAY JUNE JULY AUG.

Figure B.8. Seasonal catch per effort of freshwater drum with tow net and seine in the study ponds, May 12-August 4, 1978


Pond 1
Pond 2
Pond 3
Pond 4
Tow Net
Seine
Both
CATCH PER 100 m$^3$ OF WATER FILTERED
CATCH PER 100 m$^2$ SURFACE AREA SEINED
15 25 5 15 25 5 15 25
MAY JUNE JULY AUG.
15 25 5 15 25 5 15 25 5
MAY JUNE JULY AUG.

APPENDIX C. SEASONAL CATCH PER EFFORT OF ZOOPLANKTON IN THE STUDY PONDS, MAY 12-JULY 23, 1978

Figure C.1. Seasonal catch per effort by Van Dorn bottle of the most abundant organisms in the study ponds, May 12-July 23, 1978

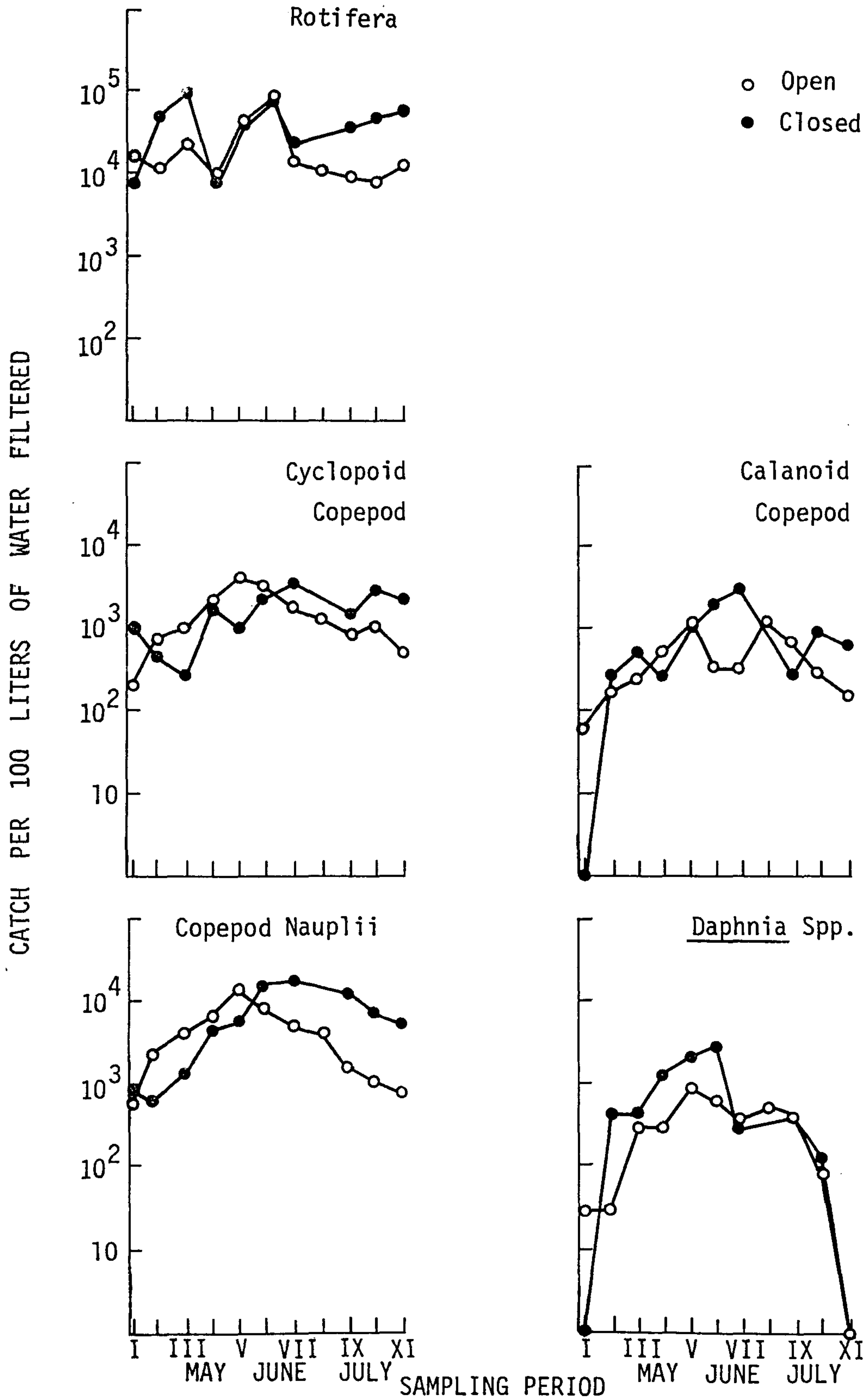

Rotifera
o Open
● Closed
Cyclopoid
Copepod
Calanoid
Copepod
Copepod Nauplii
Daphnia Spp.
CATCH PER 100 LITERS OF WATER FILTERED
10
10^2
10^3
10^4
10^5
I III V VII IX XI
MAY JUNE JULY
SAMPLING PERIOD

Figure C.2. Seasonal catch per effort of Rotifera by Van Dorn bottle in the study ponds, May 12-July 23, 1978

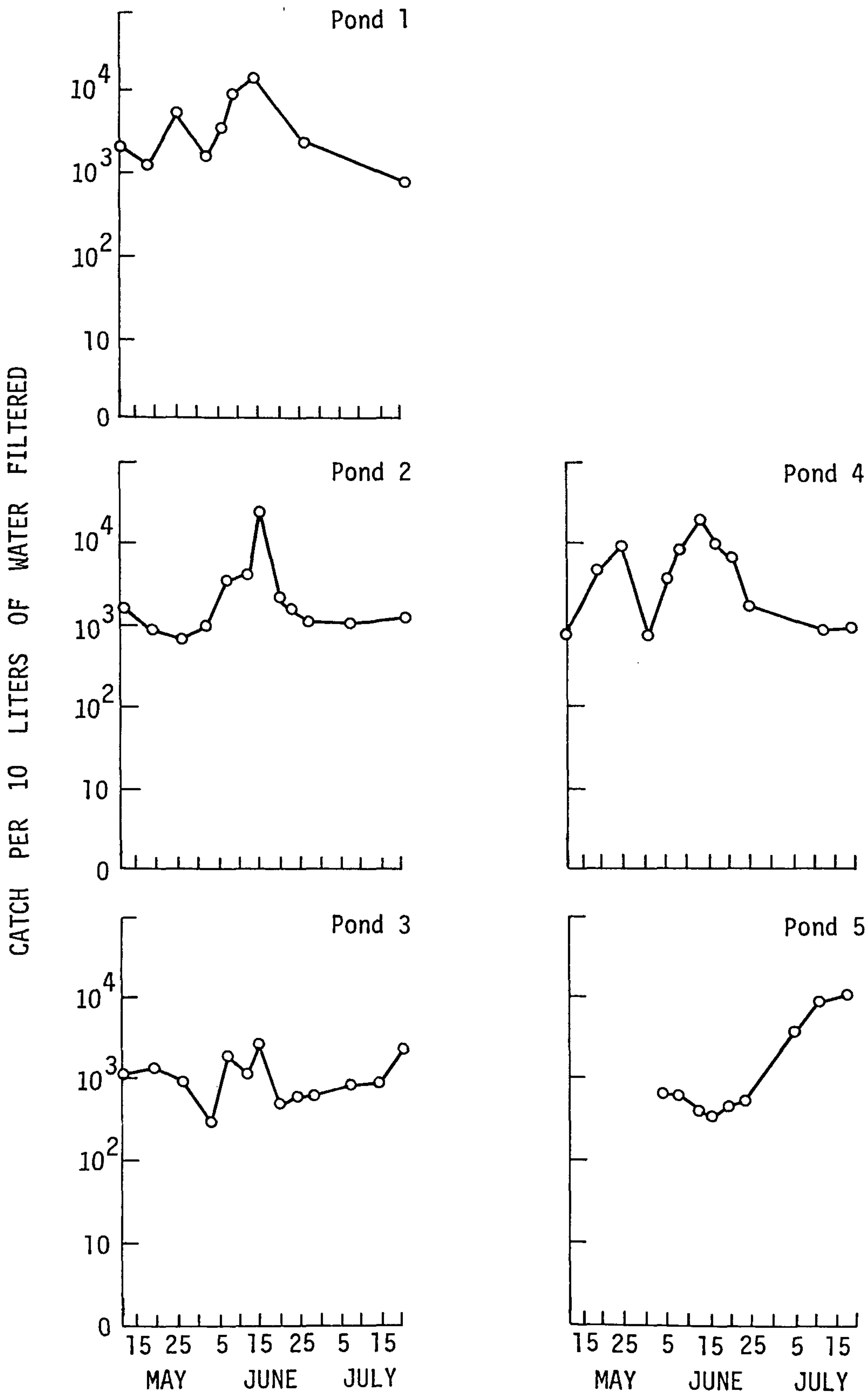

Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
CATCH PER 10 LITERS OF WATER FILTERED
$10^4$
$10^3$
$10^2$
10
0
15 25 5 15 25 5 15
MAY
JUNE
JULY

Figure C.3. Seasonal catch per effort of calanoid copepods by Van Dorn bottle in the study ponds, May 12-July 23, 1978

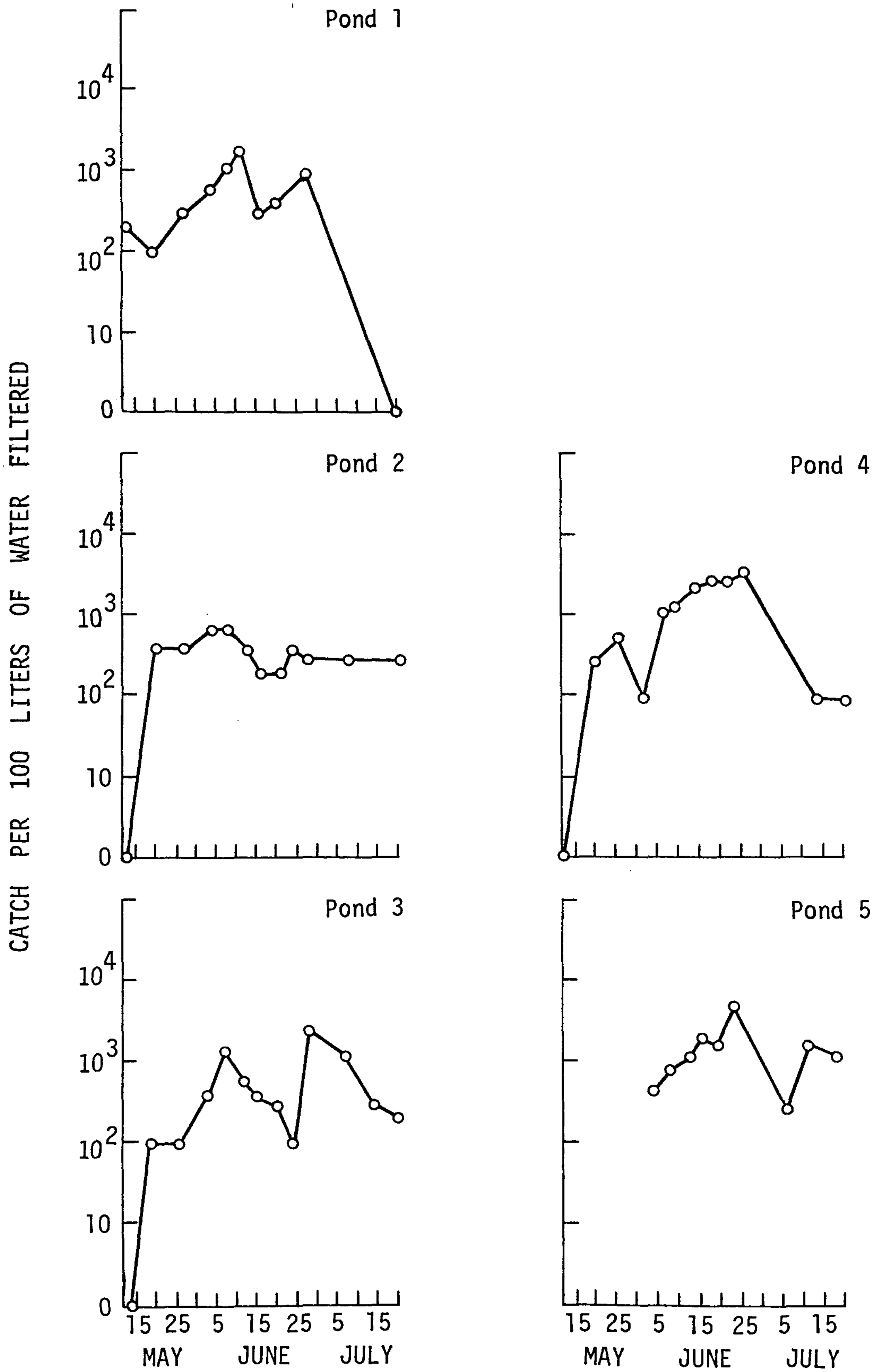

Pond 1
Pond 2
Pond 4
Pond 3
Pond 5
CATCH PER 100 LITERS OF WATER FILTERED
$10^4$
$10^3$
$10^2$
10
0
15 25 5 15 25 5 15
MAY JUNE JULY

Figure C.4. Seasonal catch per effort of cyclopoid copepods by Van Dorn bottle in the study ponds, May 12-July 23, 1978

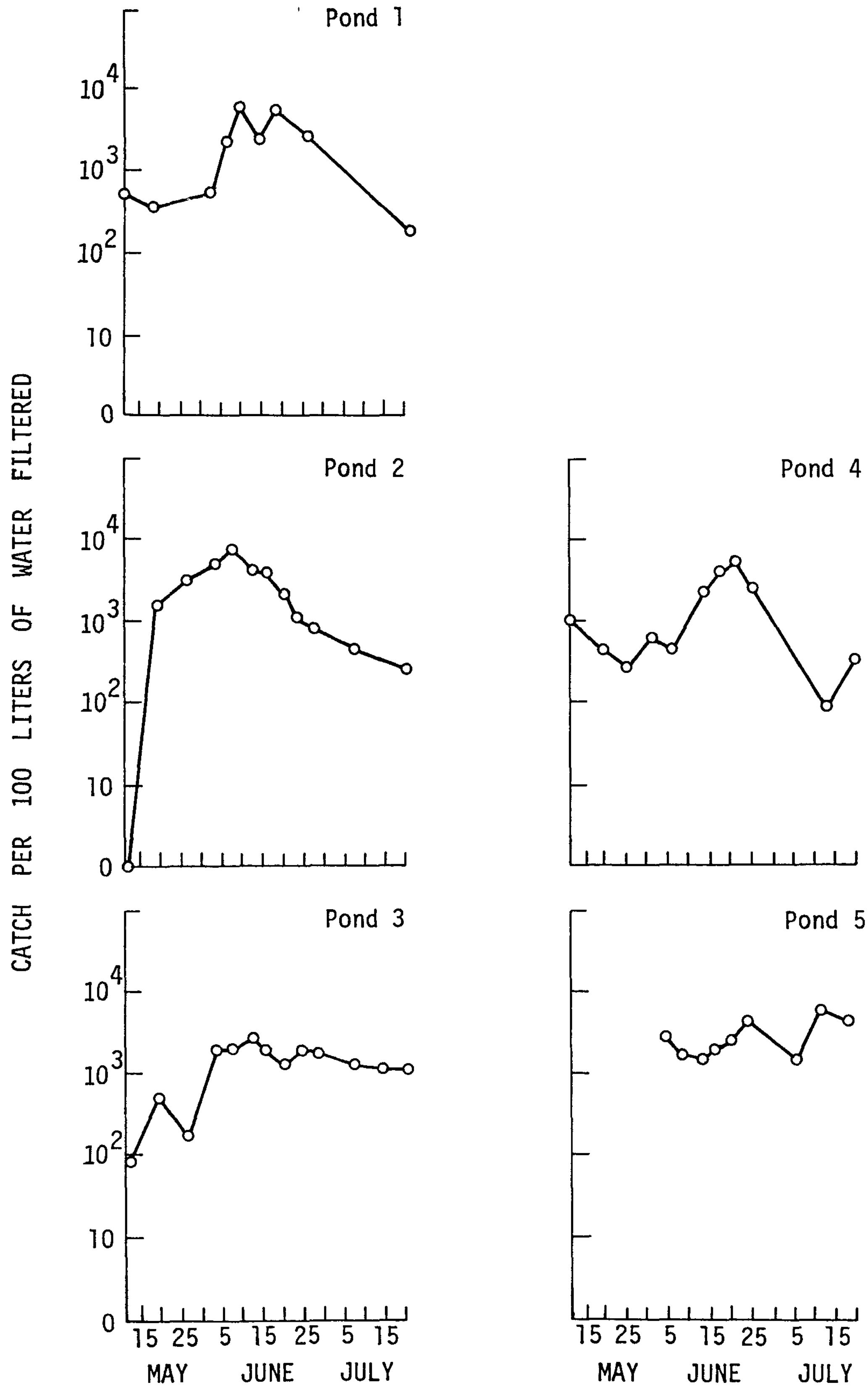
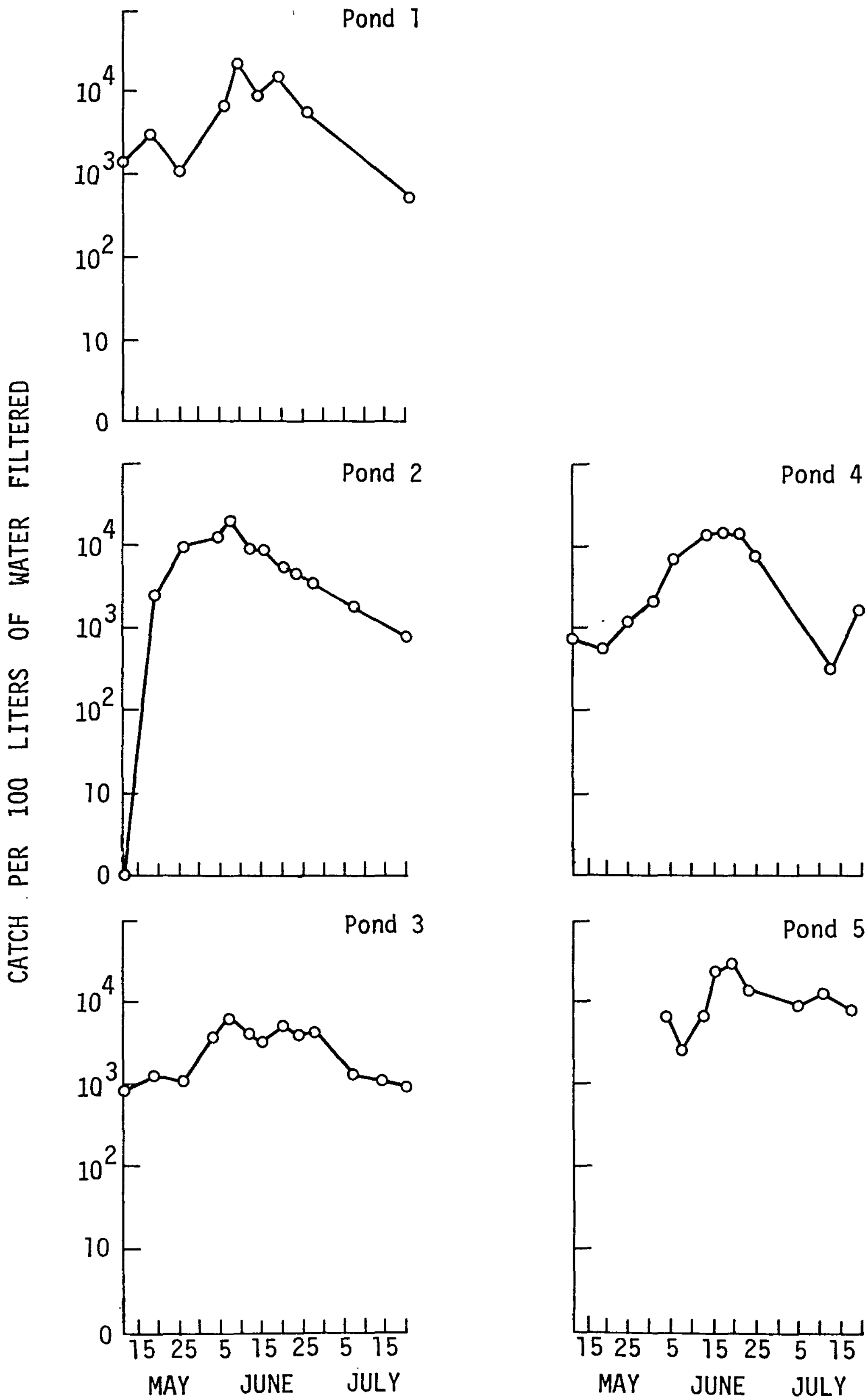
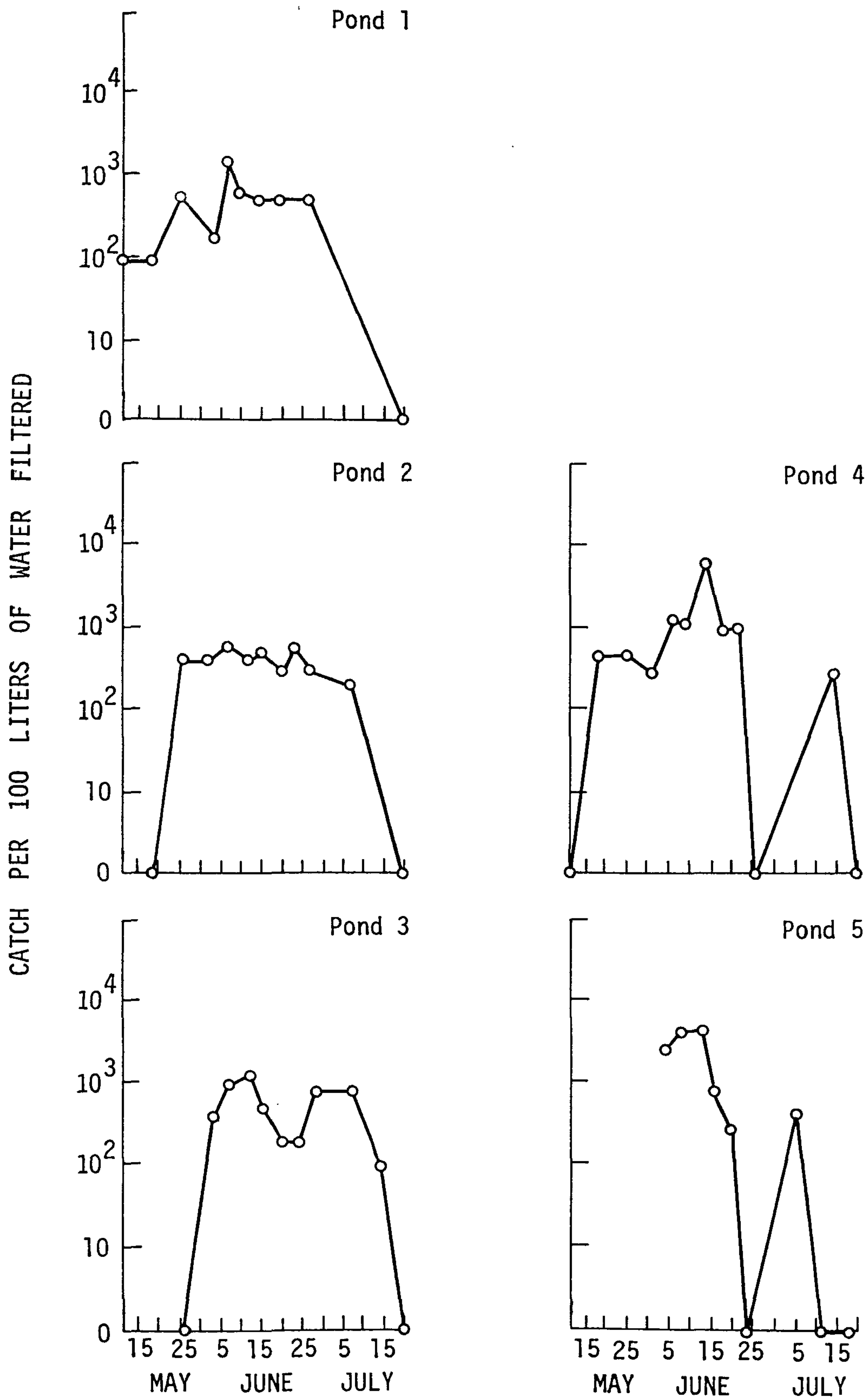

Pond 1
Pond 2
Pond 4
Pond 3
Pond 5
CATCH PER 100 LITERS OF WATER FILTERED
$10^4$
$10^3$
$10^2$
10
0
15 25 5 15 25 5 15
MAY JUNE JULY

Figure C.5. Seasonal catch per effort of copepod nauplii by Van Dorn bottle in the study ponds, May 12-July 23, 1978



CATCH PER 100 LITERS OF WATER FILTERED
Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
$10^4$
$10^3$
$10^2$
10
0
15 25 5 15 25 5 15
MAY
JUNE
JULY

Figure C.6. Seasonal catch per effort of *Daphnia* spp. by Van Dorn bottle in the study ponds, May 12-July 23, 1978


CATCH PER 100 LITERS OF WATER FILTERED
Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
10^4
10^3
10^2
10
0
15 25 5 15 25 5 15
MAY JUNE JULY

APPENDIX D. MEAN TOTAL LENGTH, STANDARD DEVIATION, RANGE, AND CALCULATED REGRESSION LINE FOR GROWTH OF FISHES IN THE STUDY PONDS

Figure D.1. Mean total length, standard deviation, range, and calculated regression line for growth of gizzard shad in the study ponds

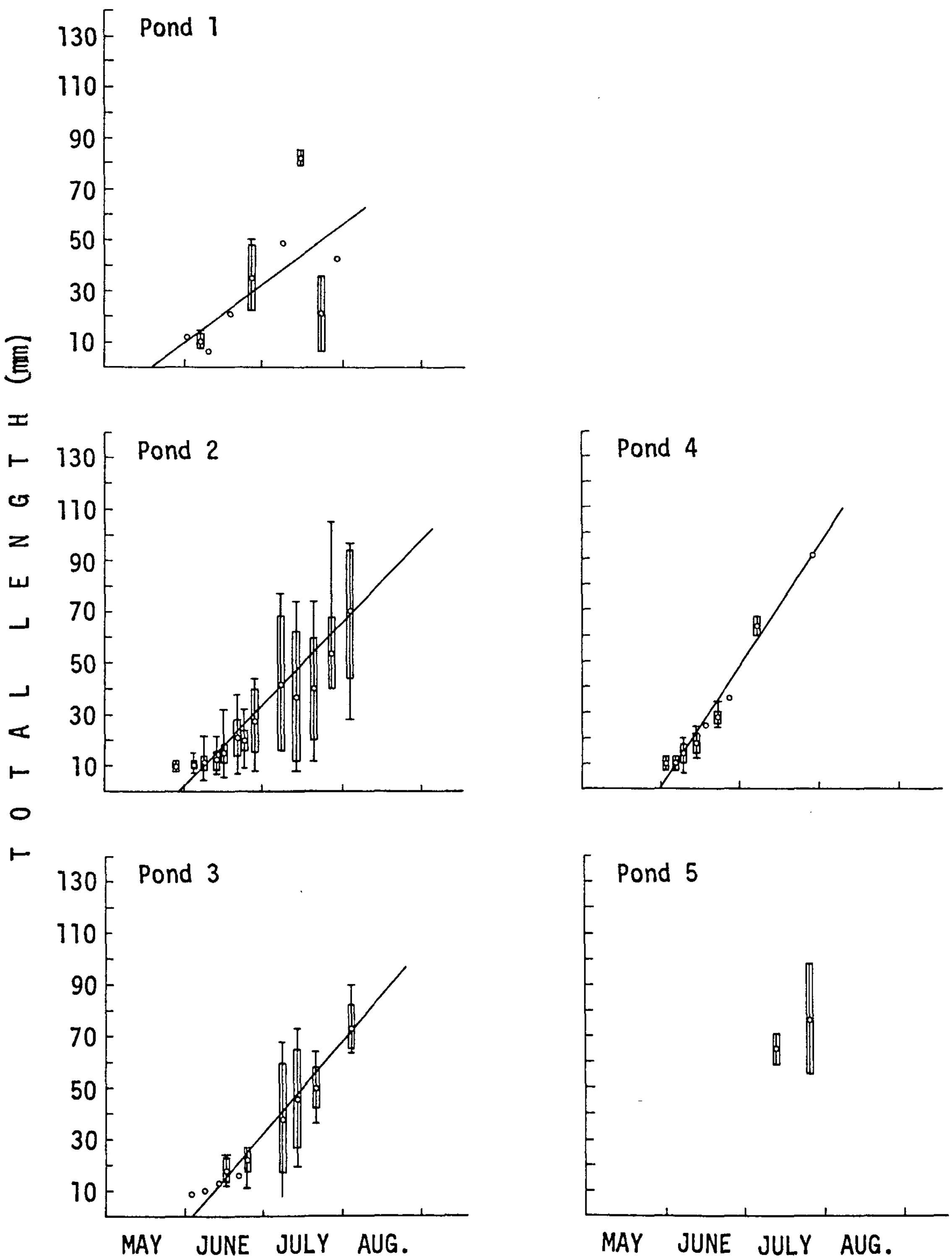

Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
130
110
90
70
50
30
10
TOTAL LENGTH (mm)
MAY
JUNE
JULY
AUG.

Figure D.2. Mean total length, standard deviation, range, and calculated regression line for growth of carp in the study ponds

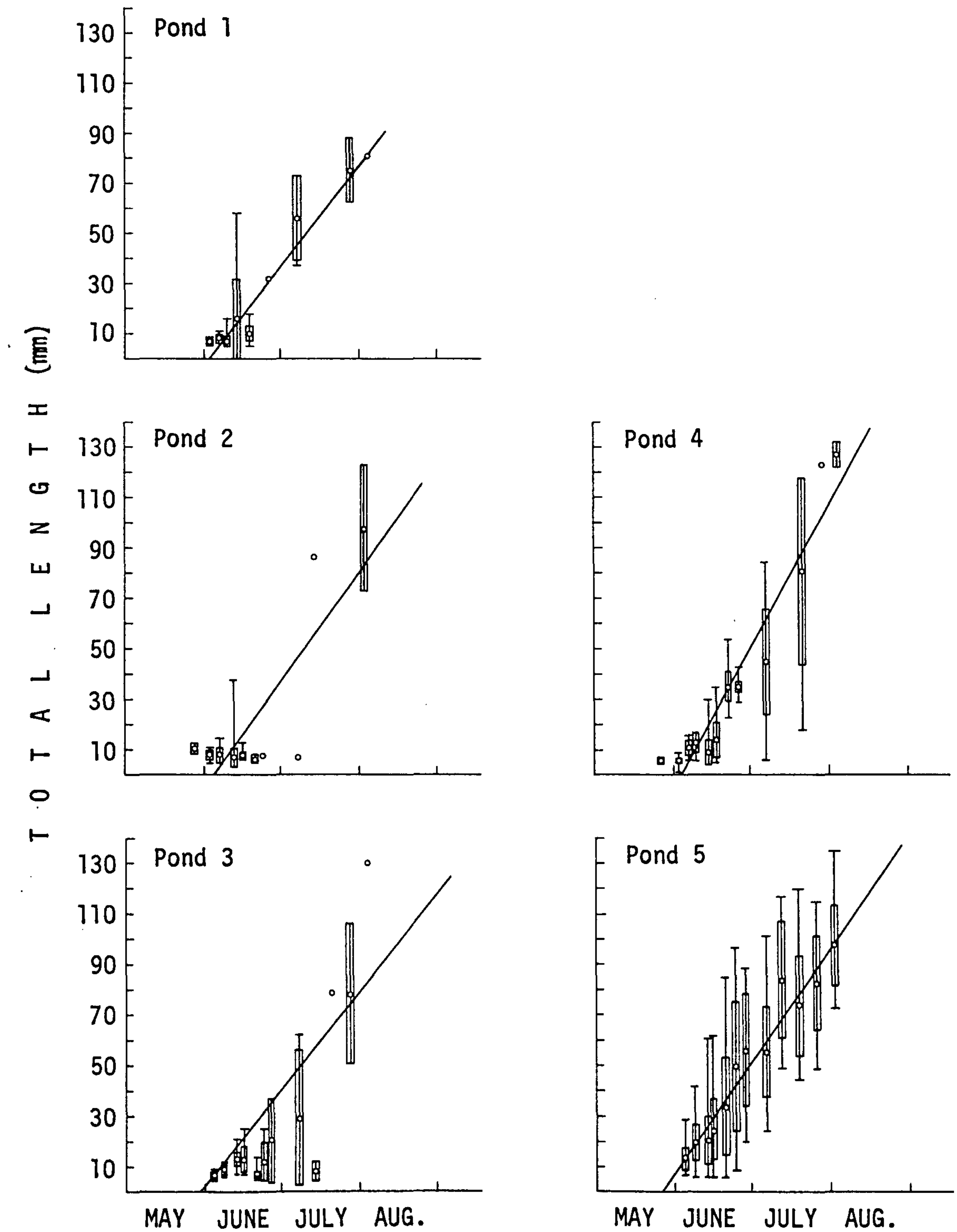

Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
TOTAL LENGTH (mm)
130
110
90
70
50
30
10
MAY
JUNE
JULY
AUG.

Figure D.3. Mean total length, standard deviation, range, and calculated regression line for growth of suckers in the study ponds

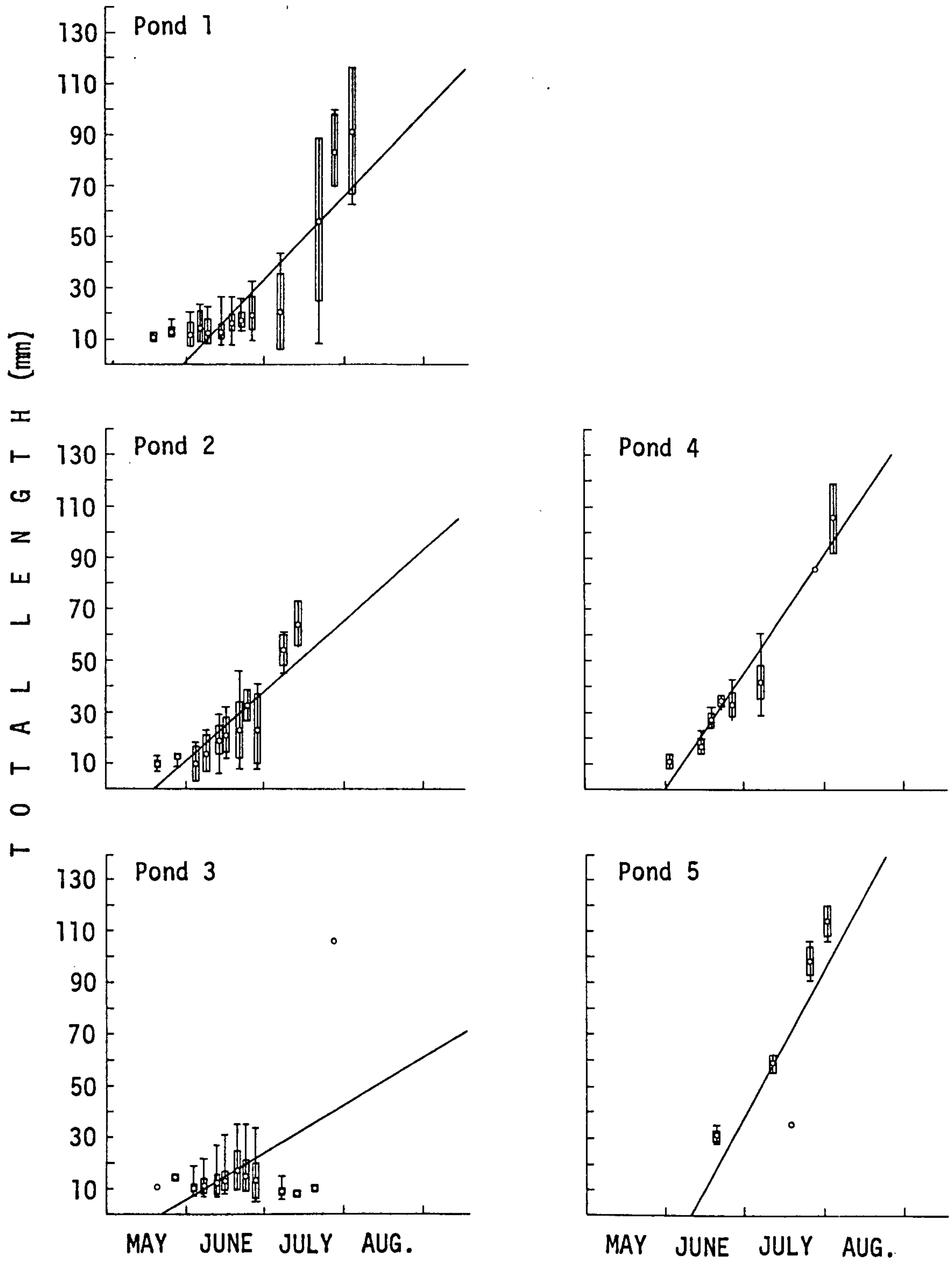

Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
TOTAL LENGTH (mm)
130
110
90
70
50
30
10
MAY
JUNE
JULY
AUG.

Figure D.4. Mean total length, standard deviation, range, and calculated regression line for growth of sunfish in the study ponds

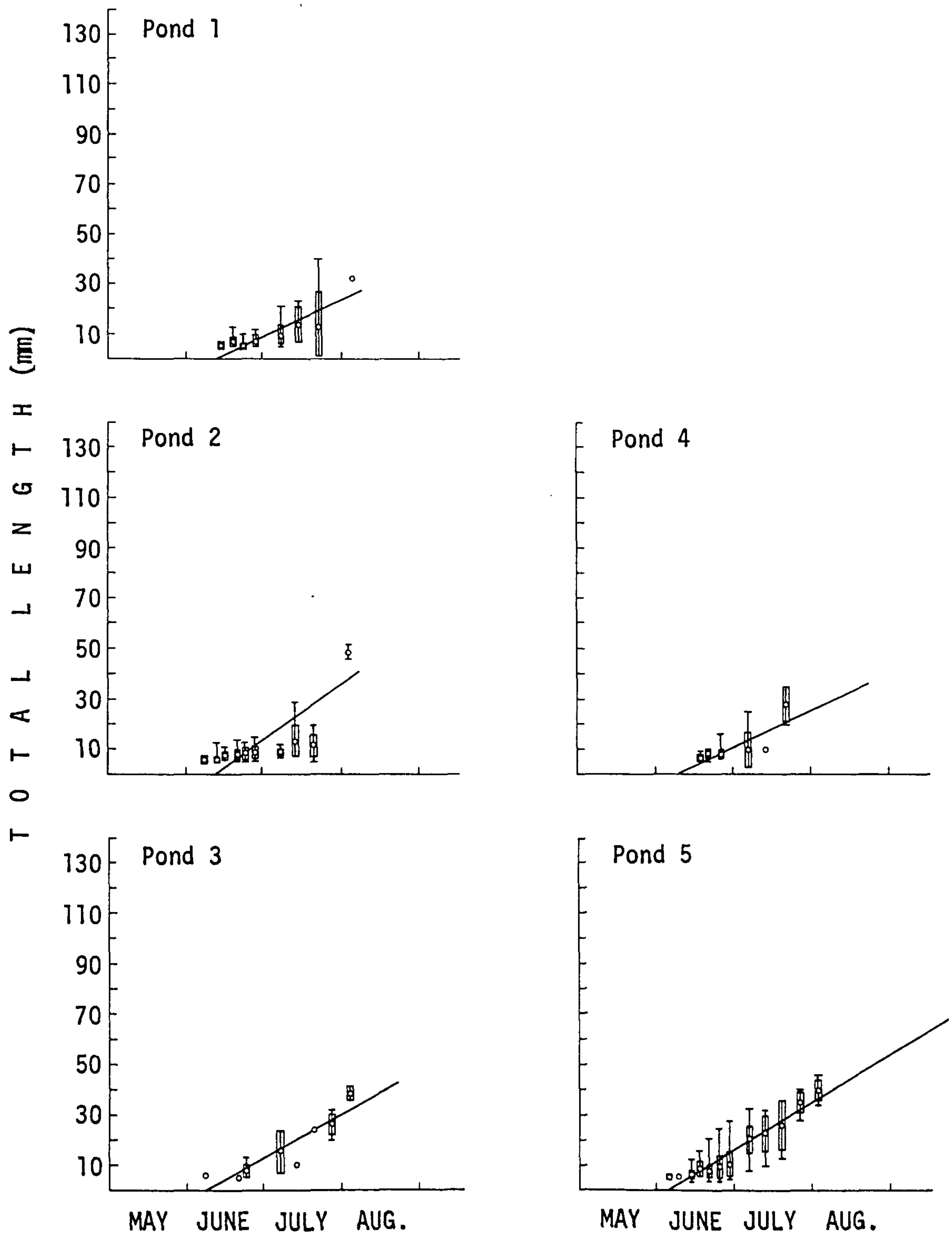
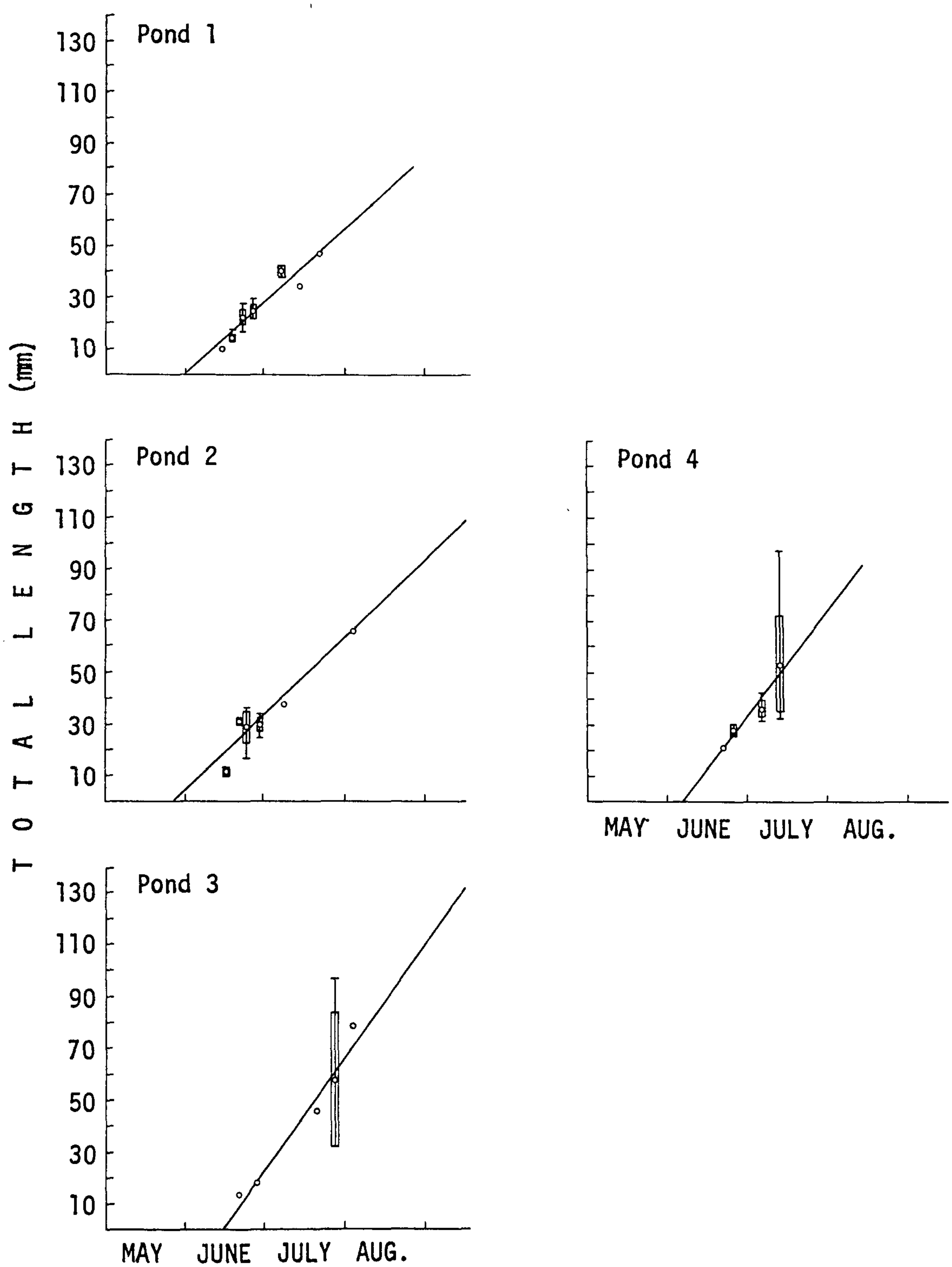
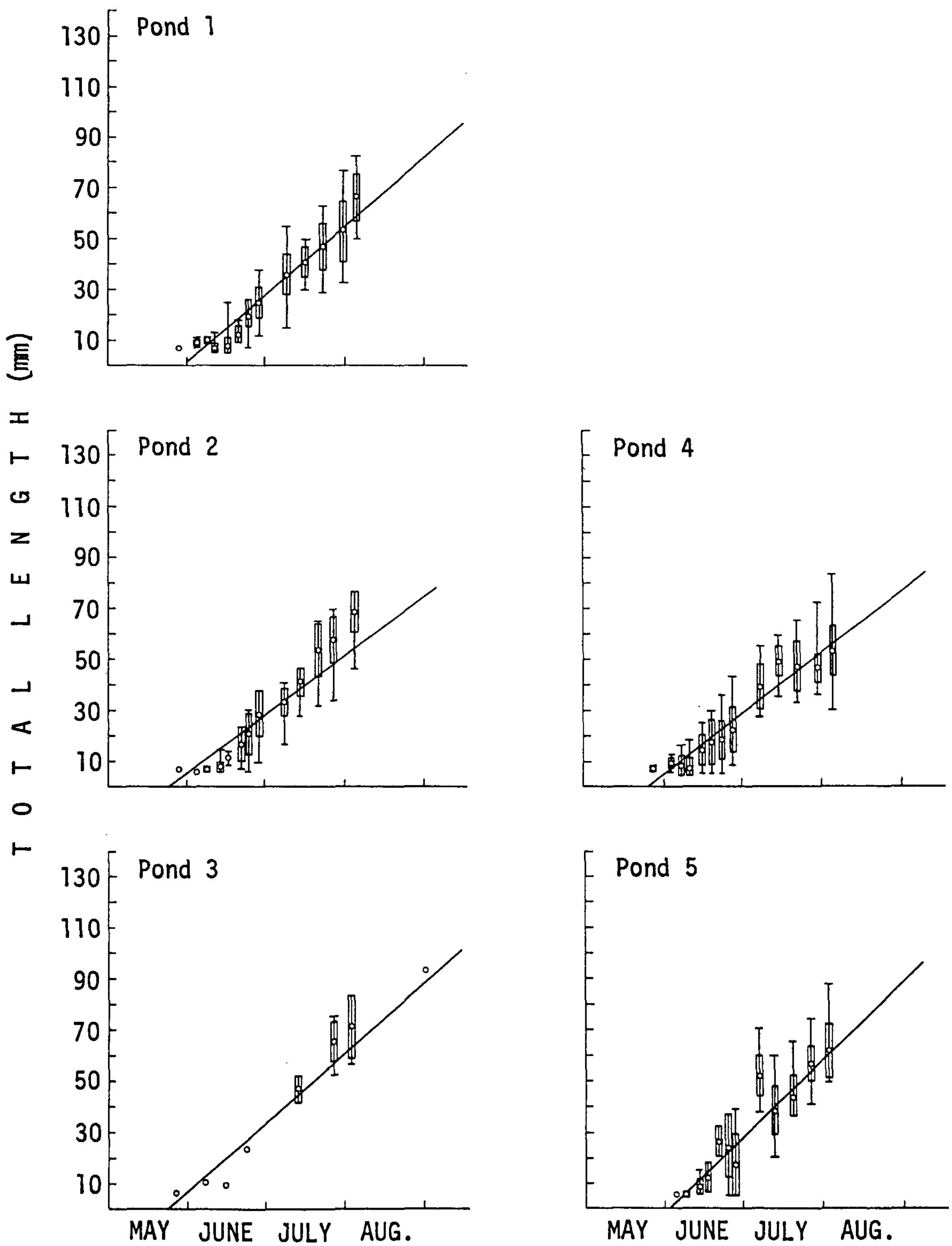

TOTAL LENGTH (mm)
Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
130
110
90
70
50
30
10
MAY
JUNE
JULY
AUG.

Figure D.5. Mean total length, standard deviation, range, and calculated regression line for growth of largemouth bass in the study ponds



Pond 1
Pond 2
Pond 3
Pond 4
TOTAL LENGTH (mm)
130
110
90
70
50
30
10
MAY
JUNE
JULY
AUG.

Figure D.6. Mean total length, standard deviation, range, and calculated regression line for growth of crappie in the study ponds



TOTAL LENGTH (mm)
Pond 1
Pond 2
Pond 3
Pond 4
Pond 5
10
30
50
70
90
110
130
MAY
JUNE
JULY
AUG.

Figure D.7. Mean total length, standard deviation, range, and calculated regression line for growth of yellow perch in the study ponds

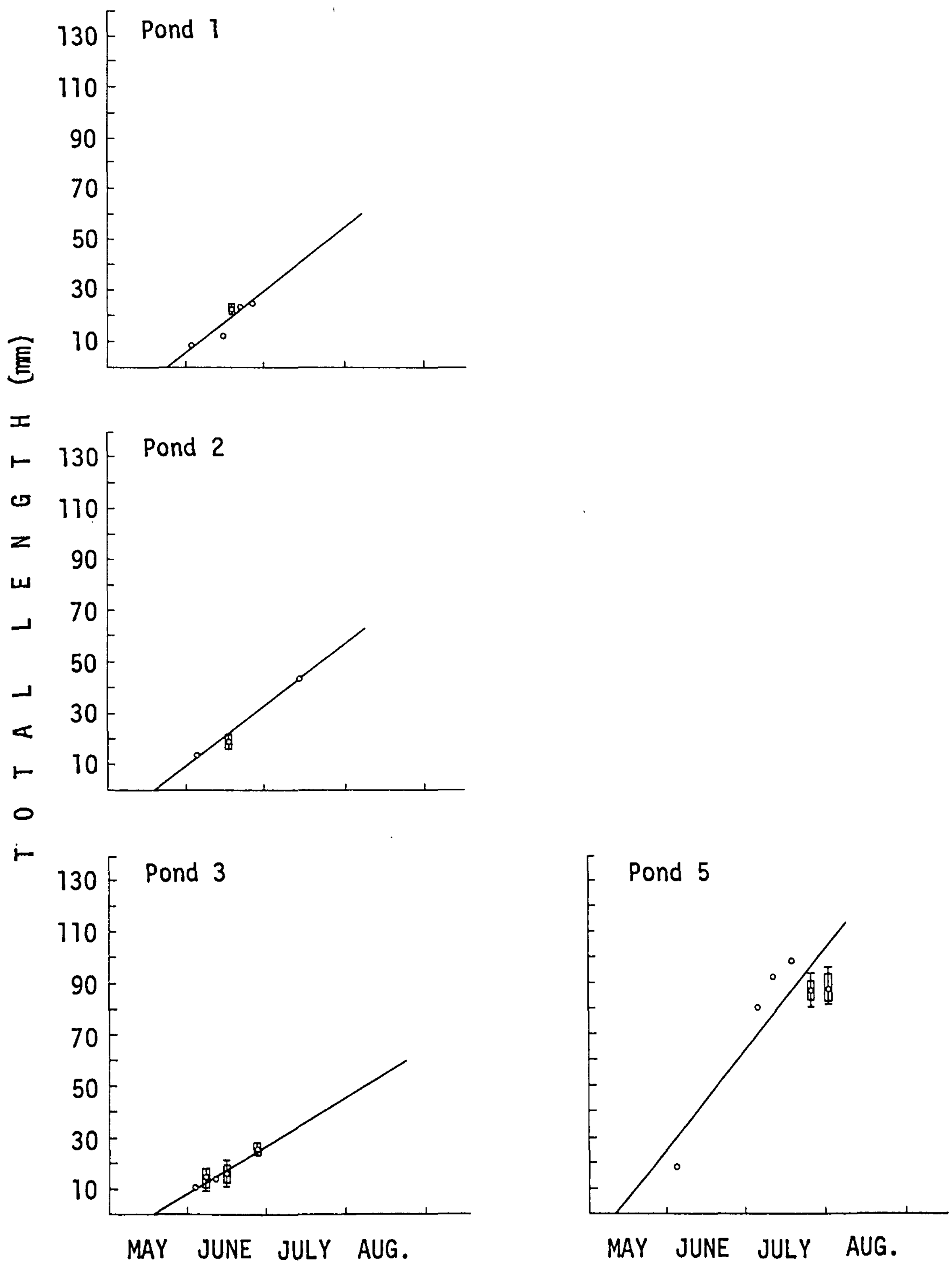
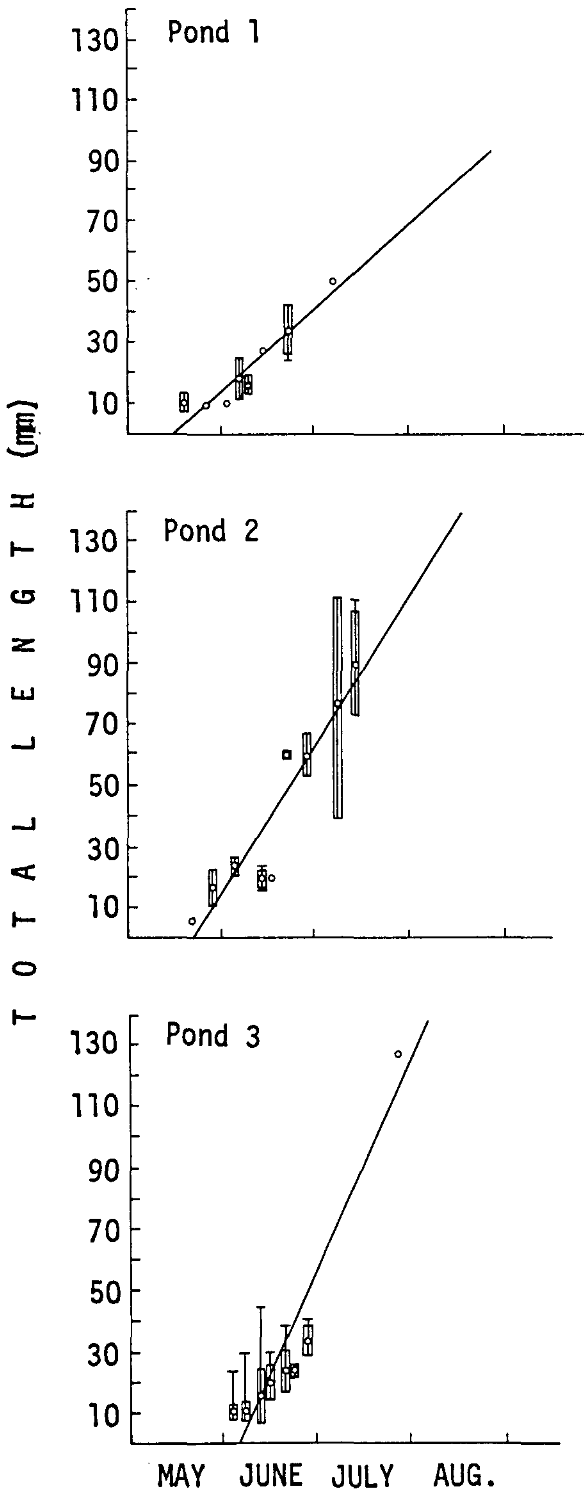

Pond 1
Pond 2
Pond 3
Pond 5
TOTAL LENGTH (mm)
130
110
90
70
50
30
10
MAY
JUNE
JULY
AUG.

Figure D.8. Mean total length, standard deviation, range, and calculated regression line for growth of sauger-walleye in the study ponds


Pond 1
Pond 2
Pond 3
130
110
90
70
50
30
10
TOTAL LENGTH (mm)
MAY
JUNE
JULY
AUG.